Water Monitoring Programs

CHAPTER 5

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Lawrence Livermore National Laboratory monitors a multifaceted system of waters that includes wastewaters, storm water, and groundwater, as well as rainfall and local surface waters. Water systems operate differently between the Livermore site and Site 300. For example, Site 300 is not serviced by a publicly owned treatment works as is the Livermore site, so different methods of treating and disposing of sanitary wastewater are used at the two LLNL sites. As described below, many different drivers determine the appropriate methods and locations among the various water monitoring programs.

In general, water samples are collected according to written standardized procedures appropriate for the medium (see Woods 2005). Sampling plans are prepared in advance by each network analyst, who is the LLNL staff person responsible for developing and implementing the specific monitoring programs or networks. The network analyst decides what analytes are to be sampled (see Appendix A) and at what frequency, incorporating any permit-specified analyses. Except for certain sanitary sewer and retention tank analytes, the analyses were usually performed by off-site California-certified contract analytical laboratories.

Sanitary Sewer Effluent Monitoring

In 2005, the Livermore site discharged an average of 1.08 million liters (ML) per day of wastewater to the City of Livermore sewer system, 4% of the total flow into the city's system. This volume includes wastewater generated by Sandia National Laboratories/ California (Sandia/California) and very small quantities (26,420 gallons in 2005) of Site 300 wastewater, which is discharged to the LLNL collection system and combines with LLNL sewage before it is released at a single point to the municipal collection system

(**Figure 5-1**). Most of the process wastewater generated at the Livermore site is collected in various retention tanks and discharged to LLNL's collection system under prior approval from LLNL's Water Guidance and Monitoring Group (WGMG) Waste Discharge Authorization Record (WDAR) approval process. In 2005, Sandia/California generated approximately 10% of the total effluent discharged from the Livermore site. LLNL's wastewater contains both sanitary sewage and process wastewater and is discharged in accordance with permit requirements and the City of Livermore Municipal Code, as discussed below.

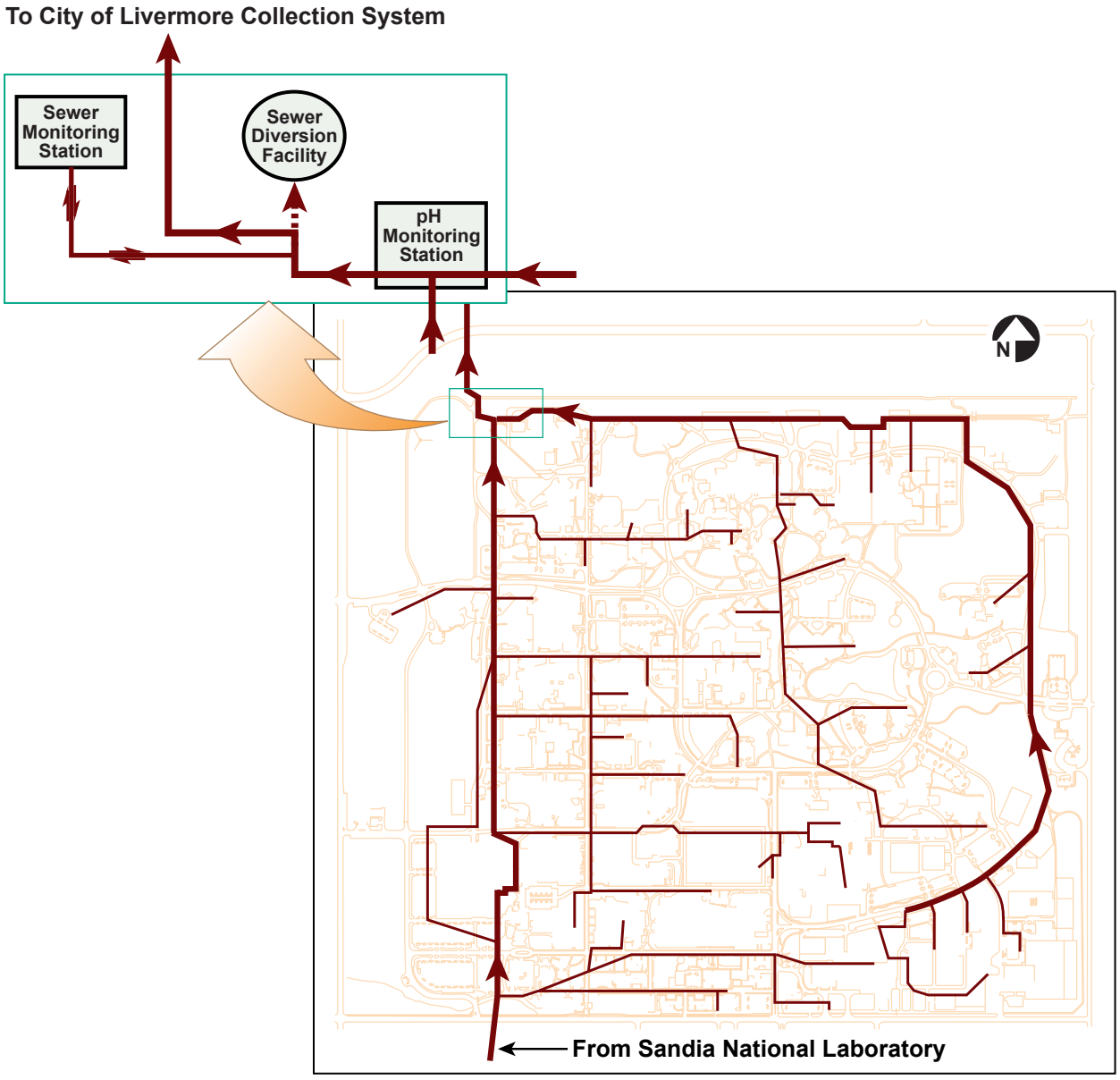


Figure 5-1. LLNL sanitary sewer system, monitoring stations, and diversion facility

Livermore Site Sanitary Sewer Monitoring Complex

LLNL's sanitary sewer discharge permit (Permit 1250, 2004/2005 and 2005/2006) requires continuous monitoring of the effluent flow rate and pH. Samplers at the Sewer Monitoring Station (SMS) collect flow-proportional composite samples and instantaneous grab samples that are analyzed for metals, radioactivity, toxic chemicals, and water-quality parameters. In addition, as a best management practice, the outflow to the municipal collection system is sampled continuously and analyzed in real time for conditions that might cause upset or pass through to the Livermore Water Reclamation Plant (LWRP) treatment process or otherwise impact the public welfare. The effluent is continuously analyzed for flow, pH, regulated metals, and gamma radioactivity. If concentrations above warning levels are detected the site effluent is automatically diverted to the Sewer Diversion Facility (SDF), and an alarm is registered at the LLNL Fire Dispatcher's Station, which is attended 24 hours a day. The monitoring system provides a continuous check on sewage control, and the LWRP is notified of contaminant alarms. Trained LLNL staff respond to all alarms to evaluate the cause and take appropriate action.

In years prior to 2005, LLNL collected monthly grab samples, monthly 24-hour composites, and weekly composites from a subsurface vault location immediately adjacent to, but outside, the SMS. Experience demonstrated a number of limitations associated with this sampling location that impacted the homogeneity of effluent samples. On December 15, 2004, the LWRP approved an LLNL request to relocate the sewer monitoring sampling location to within the SMS facility. This new sampling location was activated on December 30, 2004 (for the December 30, 2004 to January 5, 2005 weekly composite sample), and all effluent samples collected since that date have been acquired using this upgraded sampling system within the SMS.

In addition to the continuous monitoring at the SMS, LLNL monitors pH at the upstream pH Monitoring Station (pHMS) (see **Figure 5-1**). The pHMS continuously monitors pH during peak flow hours between 7 a.m. and 7 p.m. during the workweek and diverts pH discharges outside the permit range of 5 to 10 to the SDF. The pHMS duplicates the pH monitoring and diversion capabilities of the SMS but is able to initiate diversion earlier because it is located upstream of the SDF.

LLNL maintains and operates a diversion system that activates automatically when either the SMS continuous monitoring system or the pHMS detects an anomalous condition. For SMS-activated alarms, the SDF ensures that all but the first few minutes of the potentially affected wastewater flow is retained at LLNL, thereby protecting the LWRP and minimizing any potential cleanup. When the SDF is activated by the upstream pHMS for pH excursions, even the first few minutes of affected wastewater flow are

retained. Up to 775,000 L of potentially contaminated sewage can be held, pending analysis to determine the appropriate handling method. The diverted effluent may be returned to the sanitary sewer (if it meets LLNL's wastewater discharge permit limits), shipped for off-site disposal, or treated at LLNL's Radioactive and Hazardous Waste Management (RHWM) facilities and then released to the sanitary sewer. All diverted sewage in 2005 was returned to the sanitary sewer.

Radiological Monitoring Results

Work Smart Standards (WSS) establish the standards of operation at LLNL (see Chapter 2), and include the standards for sanitary sewer discharges. For radioactive material releases, complementary (rather than overlapping) sections from Department of Energy (DOE) Order 5400.5 and 10 CFR Part 20 are both part of the standards. From DOE Order 5400.5, the WSS for sanitary sewer discharges include the criteria DOE established for the application of best available technology to protect public health and minimize degradation of the environment. These criteria (the Derived Concentration Guides, or DCGs) limit the concentration of each radionuclide discharged to publicly owned treatment works. If a measurement of the monthly average concentration of a radioisotope exceeds its specific concentration limit, LLNL is required to improve discharge control measures until concentrations are again below the DOE limits. From 10 CFR Part 20, the numerical discharge limits for sanitary sewer discharges in the WSS include the annual discharge limits for radioactivity: 185 GBq (5 Ci) of tritium, 37 GBq (1 Ci) of carbon-14, and 37 GBq (1 Ci) of all other radionuclides combined. The 10 CFR Part 20 limit on total tritium activity dischargeable during a single year (185 GBq [5 Ci]) is primary over the DOE Order 5400.5 concentration-based limit for tritium for facilities such as LLNL that generate wastewater in large volumes. In addition to the DOE average concentration discharge limit for tritium and the 10 CFR Part 20 annual total discharge limit for tritium, the LWRP established in 1999 an effluent concentration discharge limit for LLNL governing daily releases of tritium. This limit is more stringent than the DOE discharge limit: it is a factor of 30 smaller and applies to a daily rather than an annualized concentration. The following discussion includes the specific radioisotopes with potential to be found in the sanitary sewer effluent at LLNL with respect to the appropriate discharge limit. (All analytical results are included in the file "Ch5 LV Wastewater" provided on the report CD.)

LLNL determines the total radioactivity contributed by tritium, gross alpha emitters, and gross beta emitters from the measured radioactivity in the monthly effluent samples. The 2005 combined release of alpha and beta sources was 0.22 GBq (0.01 Ci), which is 0.59% of the corresponding 10 CFR Part 20 limit (37 GBq [1.0 Ci]). The combined total is the sum of the alpha

and beta results shown in Table 5-1. The tritium total was 3.1 GBq (0.08 Ci), which is 0.04% of the 10 CFR Part 20 limit (185 GBq [5 Ci]).

Table 5-1. Estimated total radioactivity in LLNL sanitary sewer effluent, 2005

Radioactive emitter	Estimate based on effluent activity (GBq)[a]	Limit of sensitivity (GBq)
Tritium	3.12	1.00
Gross alpha sources	0.01	0.04
Gross beta sources	0.21	0.10

a 37 GBq = 3.7×10^{10} Bq = 1 Ci

Summary results and statistics for tritium measured in the sanitary sewer effluent from LLNL and LWRP are presented in Table 5-2. The total monthly activity is calculated by multiplying each monthly concentration by the total flow volume over which the sample was collected. (Per DOE guidance, all total annual results presented in this chapter for radionuclides are calculated by using all analytical results regardless of whether or not they are above the detection limit). The maximum daily concentration for tritium at 0.279 Bq/mL was far below the permit discharge limit (12 Bq/mL [333 pCi/mL]).

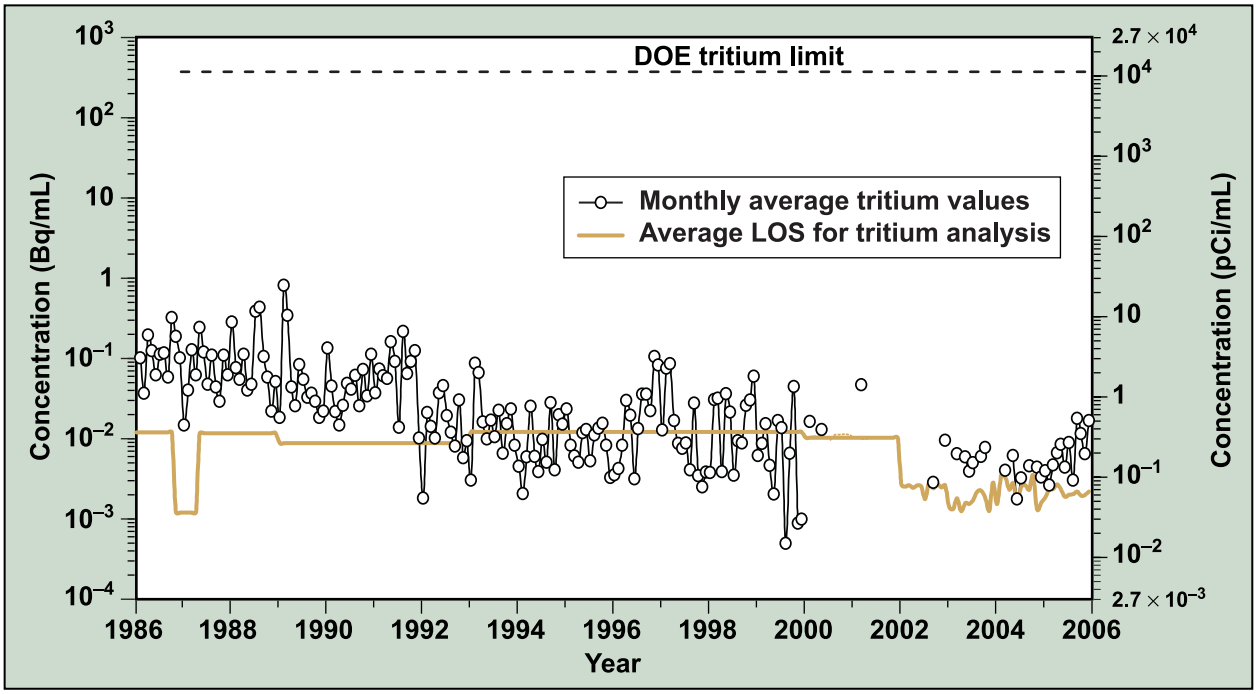
Table 5-2. Summary statistics of tritium in sanitary sewer effluents, LLNL and LWRP, 2005

Monitoring results			
	LLNL		LWRP
	Daily	Monthly	Monthly
Maximum (Bq/mL)	0.279[a]	0.018[b]	0.006[c]
Median (Bq/mL)	0.002	0.007	0.002
LLNL annual total (GBq)	3.12		

Discharge limits for LLNL effluent			
	Discharge limit	Monitoring results as percentage of limit	
		Maximum	Median
LWRP permit daily (Bq/mL)	12	2.33%	0.02%
DOE annualized discharge limit for application of BAT[d] (Bq/mL)	370	0.005%[e]	0.0005%[e]
10 CFR 20 annual total (GBq)	185	1.7%	

a This daily result is for a December sample.
b This is the monthly value for September. All monthly values above limit of sensitivity are plotted in Figure 5-2.
c This is the monthly result for April.
d The DOE annualized discharge limit for application of best available technology (BAT) is five times the derived concentration guide (DCG: ingested water) for each radionuclide released.
e Monitoring results as a percentage of limit are calculated using the LLNL monthly sample concentration and the DOE annualized discharge limit.

The historical trend in the monthly concentration of tritium is shown in **Figure 5-2** (before 2002, the figure shows the monthly averages calculated from weekly data). Also included in the figure are the limit of sensitivity (LOS) values for the tritium analysis and the DOE tritium limit (370 Bq/mL [0.01 µCi/mL]).



Notes:
- Only values above the limit of sensitivity (LOS) of the analytical method used are plotted.
- The DOE annualized discharge limit for application of best available technology (BAT) is five times the derived concentration guide (DCG: ingested water) for each radionuclide released.

Figure 5-2. Historical tritium concentrations in the Livermore site sanitary sewer effluent

The concentrations of plutonium-239 and cesium-137 measured in the sanitary sewer effluent from LLNL and LWRP and in LWRP sludge are presented in **Tables 5-3** and **5-4**, respectively. The plutonium and cesium results are from monthly composite samples of LLNL and LWRP effluent, and quarterly composites of LWRP sludge. For 2005, the annual total discharges of cesium-137 and plutonium-239 were far below the DOE DCGs. Plutonium discharged in LLNL effluent is ultimately concentrated in LWRP sludge. The median plutonium concentration observed in 2005 sludge (**Table 5-4**), is many times lower than the EPA preliminary remediation goal for residential soil (93 mBq/dry g [2.5 pCi/dry g]) and is 2200 times lower than the remediation goal for industrial or commercial soil (370 mBq/dry g [10 pCi/dry g]).

Table 5-3. Cesium and plutonium in LLNL and LWRP sanitary sewer effluents, 2005

Month	Cesium-137 (µBq/mL)				Plutonium-239 (nBq/mL)			
	LLNL		LWRP		LLNL		LWRP	
	Radioactivity	MDC[a]	Radioactivity	MDC[a]	Radioactivity	MDC[a]	Radioactivity	MDC[a]
Jan	–8.21 ± 7.4	6.1	1.11 ± 6.0	5.4	11.6 ± 8.0	8.6	0.97 ± 2.2	3.6
Feb	–1.22 ± 6.9	6.0	0.33 ±5.9)	5.3	9.62 ± 6.8	6.8	–2.22 ± 1.7	5.9
Mar	3.60 ± 7.0	6.2	3.33 ± 5.8	5.3	16.4 ± 7.8	5.0	2.84 ± 3.6	4.9
Apr	–0.76 ± 5.9	5.3	–0.43 ± 7.0	6.1	6.18 ± 5.1	5.5	–0.99 ± 1.0	3.9
May	–0.07 ± 6.7	5.9	–0.14 ± 5.9	5.3	8.21 ± 5.6	5.4	1.26 ± 3.0	4.9
Jun	–3.35 ± 6.6	5.6	1.40 ± 5.7	5.2	0.27 ± 1.0	2.4	38.5 ± 11	3.2
Jul	–2.86 ±6.8	5.8	–2.04 ± 6.0	5.3	95.5 ± 21	3.5	1.22 ± 2.1	3.3
Aug	3.46 ± 6.6	5.9	–1.08 ± 5.6	5.0	50.3 ±16	7.6	7.51 ± 5.1	4.7
Sep	–0.41 ± 5.6	5.0	–1.28 ± 6.5	5.7	26.0 ± 10.6	6.1	3.04 ± 4.1	5.6
Oct	2.07 ± 5.4	4.9	0.95 ± 6.3	5.6	11.1 ± 16	21.6	0.62 ± 1.7	3.2
Nov	0.56 ± 6.3	5.5	–0.13 ± 5.4	4.9	15.7 ± 7.4	5.2	–0.82 ± 2.2	4.8
Dec	1.43 ± 6.1	5.4	–2.47 ± 5.4	4.8	35.5 ± 17	12	–2.57 ± 2.7	7.0
Median	–0.24		–0.13		13.7		1.10	
	Annual LLNL total discharge by radioisotope							
	Cesium-137				Plutonium-239			
Bq/y[b]	NA[c]				9.64×10^{3}			
Ci/y[b]	NA[c]				2.60×10^{-7}			
	Fraction of limit [d]							
DOE 5400.5 DCG[e]	NA[c]				3.69×10^{-8}			

Note: Results in this table are reported as radioactivity (the measured concentration and a ± 2σ counting uncertainty) along with the detection limit or minimum detectable concentration (MDC). A measured concentration exhibiting a 2σ counting uncertainty greater than or equal to the measured concentration is considered a nondetection (see Chapter 9).

a MDC = minimum detectable concentration

b 1 Ci = 3.7×10^{10} Bq

c Because the median value for Cs-137 is negative it cannot be compared to a positive limit. On average no measurable quantity of Cs-137 was released in 2005.

d Fraction of limit calculations are based on the annual total discharge for a given isotope and the corresponding concentration-based limit (0.56 and 0.37 Bq/mL for cesium-137 and plutonium-239, respectively) multiplied by the annual volume of Livermore site effluent.

e DCG = Derived Concentration Guide

Table 5-4. Radioactivity of cesium and plutonium in LWRP sludge, 2005

Month	Cesium-137 (mBq/dry g)[a]	Plutonium-239 (mBq/dry g)
Mar	<0.85	0.144 ± 0.038
Jun	<0.90	0.083 ± 0.021
Sep	<1.06	0.203 ± 0.051
Dec	<0.63	0.194 ± 0.050
Median	0.88	0.169

Note: Sludge from LWRP digesters is dried before analysis. The resulting data indicate the cesium and plutonium concentration of the sludge prepared by LWRP for disposal at the Vasco Road Landfill in Alameda County.

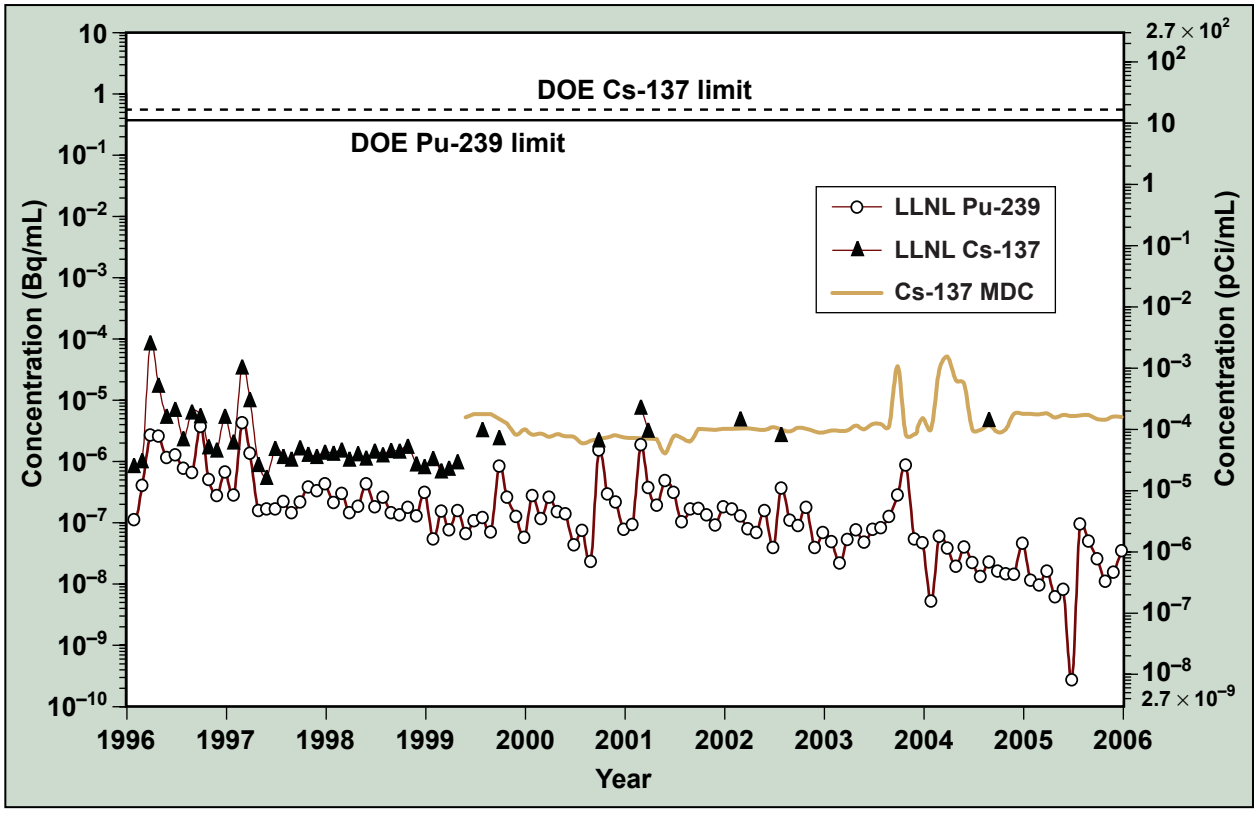
a Results are reported as radioactivity (the measured concentration ± 2σ counting uncertainty). A measured concentration exhibiting a 2σ counting uncertainty greater than or equal to 100% is considered to be a nondetection and is reported with a less than (<) symbol. See Chapter 9.

Figure 5-3 summarizes the cesium-137 and plutonium-239 monitoring data over the past 10 years. The historical levels for plutonium-239 observed since 1996 averaged approximately 1 μBq/mL (3×10^{-5} pCi/mL). These historical levels generally are 0.0003% of the DOE DCG for plutonium-239. The cyclic nature of the data in **Figure 5-3** suggests a potential frequency relationship in LLNL sewer lines for radionuclide buildup and subsequent liberation by line cleaning. Regardless, the higher plutonium and cesium concentrations are all well below applicable DOE DCGs.

LLNL also compares annual discharges with historical values to evaluate the effectiveness of ongoing discharge control programs. **Table 5-5** summarizes the radioactivity in sanitary sewer effluent over the past 10 years. During 2005, a total of 3.12 GBq (0.08 Ci) of tritium was discharged to the sanitary sewer, an amount that is well within environmental protection standards and is comparable to the amounts discharged during the past 10 years.

Nonradiological Monitoring Results

LLNL monitors sanitary sewer effluent for chemical and physical parameters at different frequencies depending on the intended use of the result. For example, LLNL's wastewater discharge permit requires LLNL to collect monthly grab samples and 24-hour composites, weekly composites, and daily composites. Once a month, a 24-hour, flow-proportional composite is collected and analyzed; this is referred to as the monthly 24-hour composite in the



Notes: The DOE annualized discharge limit for application of best available technology (BAT) is five times the derived concentration guide (DCG: ingested water) for each radionuclide released.

Figure 5-3. Average monthly plutonium and cesium concentrations in LLNL sanitary sewer effluent

discussion below. The weekly composite refers to the flow-proportional samples collected over a 7-day period continuously throughout the year. The daily composite refers to the flow-proportional sample collected over a 24-hour period, also collected continuously throughout the year. LLNL's wastewater discharge permit specifies that the effluent pollutant limit (EPL) is equal to the maximum pollutant concentration allowed per 24-hour composite sample. Only when a weekly composite sample concentration is at or above 50% of its EPL are daily samples, collected during the corresponding period, analyzed to determine if any of their concentrations are above the EPL.

To better understand the characteristics of the Livermore site sanitary sewer effluent, LLNL also tracks flow-weighted monthly concentrations for all regulated metals in LLNL's sanitary sewer effluent; **Table 5-6** presents the flow-weighted monthly concentrations for 2005. To obtain these concentrations, each weekly composite is weighted by the total flow volume for the period during which the sample was collected. (Daily flow volumes and sample results for the 2005 weekly composites are included in the file "Ch5 LV Wastewater" provided on the report CD.) This flow-weighted monthly

Table 5-5. Historical radioactive liquid effluent releases from the Livermore site, 1995–2005

Year	Tritium (GBq)	Plutonium-239 (GBq)
1995	6.0	1.2×10^{-4}
1996	12[a]	4.2×10^{-4}
1997	9.1	2.1×10^{-4}
1998	10	0.77×10^{-4}
1999	7.1	0.68×10^{-4}
2000	5.0	0.96×10^{-4}
2001	4.9	1.1×10^{-4}
2002[b]	0.74	0.42×10^{-4}
2003[b]	1.11	0.51×10^{-4}
2004[b]	1.34	1.16×10^{-5}
2005[b]	3.12	9.64×10^{-6}

a In 1995, Sandia/California ceased all tritium facility operations; therefore, the annual tritium totals beginning with the 1996 value do not include contributions from Sandia/California.

b Starting in 2002, following DOE guidance, actual analytical values instead of LOS values were used to calculate total.

concentration represents the characteristic concentration for that month. During 2005, the month-to-month characteristic concentrations for each metal show generally lower values and less variation than the trends observed in past years. These results follow from the improved homogeneity of composite effluent samples, made possible by the upgraded sampling system within the SMS. In **Table 5-6**, the 2005 median flow-weighted concentration for each metal is shown and compared with the EPL. These median flow-weighted monthly concentrations remained well below (less than 5%) their respective EPLs for all nine regulated metals.

Figure 5-4 presents historical trends for the monthly 24-hour composite sample results from 2000 through 2005 for eight of the nine regulated metals; cadmium is not presented because this metal was not detected above the practical quantitation limit (PQL) in any of the 2000 through 2005 monthly sampling events. Typical PQLs for the regulated metals in LLNL sanitary effluent are shown in **Table 5-6**. (Sample results for the 2005 monthly 24-hour composites are included in the file "Ch5 LV Wastewater" provided on the report CD.) All of the monthly 24-hour composite samples were in compliance with LLNL's wastewater discharge permit limits. The 2005

results show concentrations of copper, and to a lesser degree both lead and zinc, at levels routinely above their respective PQLs; silver, arsenic, chromium, mercury, and nickel are rarely detected. (The elevated values reported for arsenic and nickel in June 2005 are analytical artifacts, resulting from matrix interference.) While these observations are generally consistent with the data trends from 2000 through 2004, the concentrations of those metals detected in 2005 have shown a downward trend. For example, the monthly 24-hour composite concentrations of copper and zinc, which peaked in 2004 at 28% and 16% of their respective EPLs, did not exceed 11% and 6%, respectively, of those same EPLs in 2005. As noted in the discussion of **Table 5-6** results, these trends are consistent with the improved homogeneity of composite effluent samples, made possible by the upgraded sampling system within the SMS.

Table 5-6. Flow-weighted monthly concentrations for regulated metals in LLNL sanitary sewer effluent (mg/L), 2005

Month	Ag	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
Jan	<0.010	<0.0020	<0.0050	<0.010	0.034	<0.00020	<0.0050	<0.0020	0.10
Feb	<0.012	0.0023	<0.0050	<0.012	0.032	<0.00020	<0.0050	<0.0020	0.088
Mar	<0.019	0.0021	<0.0050	<0.019	0.032	<0.00020	<0.0050	0.0023	0.083
Apr	<0.010	0.0022	<0.0050	<0.010	0.036	<0.00020	<0.0050	0.0022	0.10
May	<0.010	0.0024	<0.0050	<0.010	0.052	<0.00020	<0.0050	0.0053	0.085
Jun	<0.010	0.0033	<0.0050	<0.010	0.061	<0.00020	0.0051	0.0030	0.078
Jul	<0.010	0.0021	<0.0050	<0.010	0.068	<0.00020	0.0053	0.0059	0.081
Aug	<0.010	0.0021	<0.0050	<0.010	0.050	<0.00020	<0.0050	0.0030	0.088
Sep	<0.010	0.0021	<0.0050	<0.010	0.052	<0.00020	0.0050	0.0032	0.10
Oct	<0.010	0.0021	<0.0050	<0.010	0.047	<0.00020	0.0051	0.0022	0.079
Nov	<0.010	0.0021	<0.0050	<0.010	0.040	<0.00020	0.0063	<0.0020	0.078
Dec	<0.010	0.0023	<0.0050	<0.010	0.043	<0.00020	<0.0050	0.0036	0.070
Median	<0.010	0.0021	<0.0050	<0.010	0.045	<0.00020	<0.0050	0.0026	0.084
IQR[a]	—[b]	0.00019	—[b]	—[b]	0.016	—[b]	—[b]	0.0011	0.012
EPL[c]	0.20	0.06	0.14	0.62	1.0	0.01	0.61	0.20	3.00
Median fraction of EPL	<0.05	0.04	<0.04	<0.02	0.04	<0.02	<0.01	0.01	0.03
PQL[d]	0.010	0.0020	0.0050	0.010	0.010	0.00020	0.0050	0.0020	0.050

Note: Monthly values are presented with less-than signs when all weekly composite sample results for the month are below the detectable concentration.

a IQR = Interquartile range

b Because of the large number of nondetects, the interquartile range cannot be calculated. See Chapter 9.

c EPL = Effluent pollutant limit (LLNL Wastewater Discharge Permit 1250, 2004/2005, and 2005/2006)

d PQL = practical quantitation limit (These limits are typical values for sanitary sewer effluent samples.)

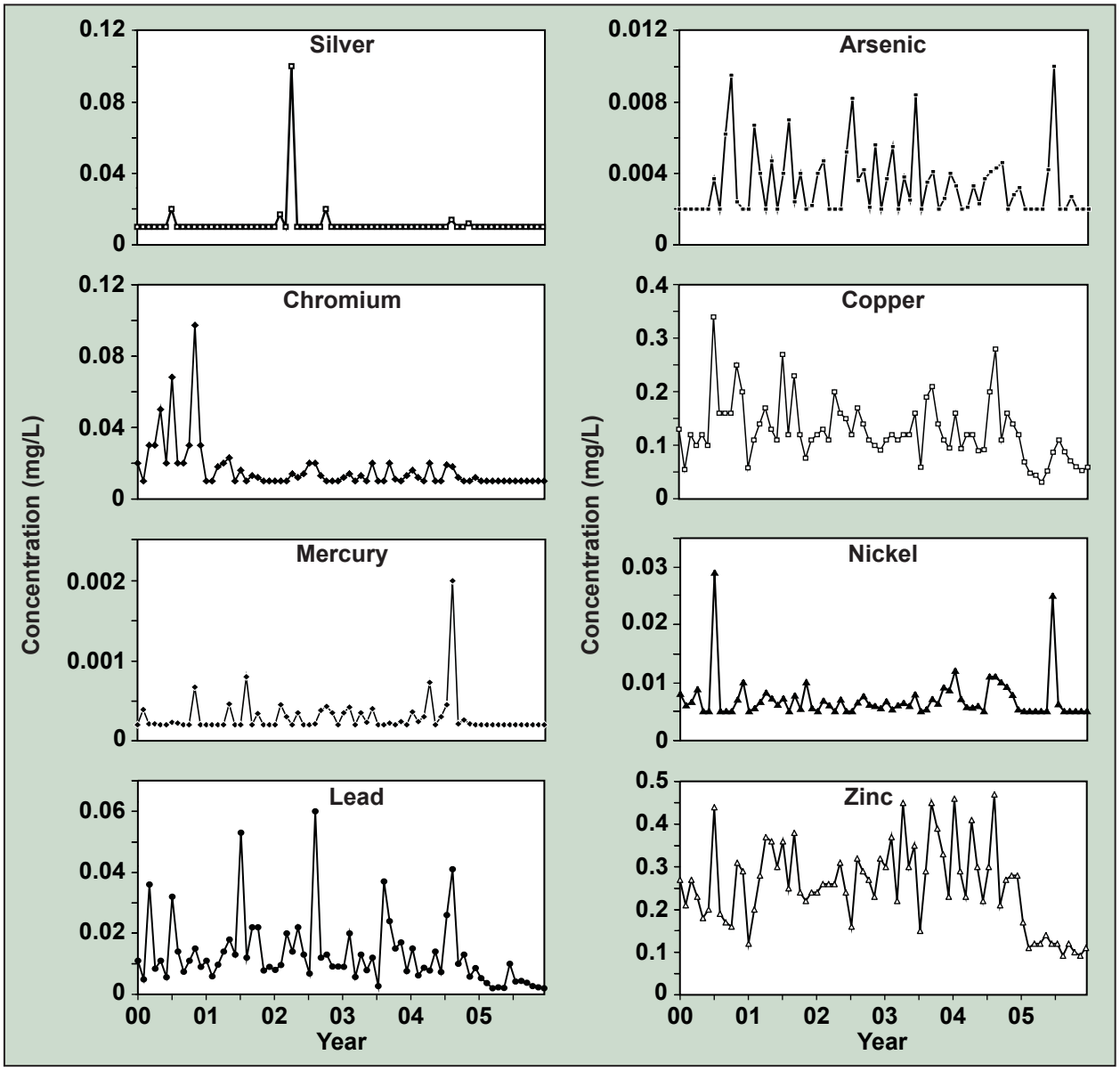


Figure 5-4. Monthly 24-hour composite sample concentrations for eight of the nine regulated metals in LLNL sanitary sewer effluent showing historical trends

The monthly 24-hour composite and weekly composite concentrations for 2005 are presented in **Figure 5-5** for eight of nine regulated metals as a percentage of the corresponding EPL. As in past years, cadmium results are not presented because the metal was not detected above the PQL in any of the weekly or monthly samples. In 2005, an additional three (silver, chromium, and mercury) of the nine regulated metals were not detected above PQLs in any of the weekly or monthly samples; these results are presented however, to facilitate comparisons with previous Environmental Reports. As discussed above, all of the regulated metal concentrations in the

monthly 24-hour composite samples are well below their respective EPLs. Similarly, none of the weekly composite samples showed metal concentrations above 50% of their respective EPLs, the permit-specified action limit that would require additional analyses of daily samples. The highest percentage of EPL reported during 2005 was for silver (at 25% of EPL) in the March 3–9 weekly composite. The corresponding silver concentration (<0.050 mg/L), however, was based on an elevated PQL. All other reported metal concentrations were <20% of the respective EPLs, with most being <10%.

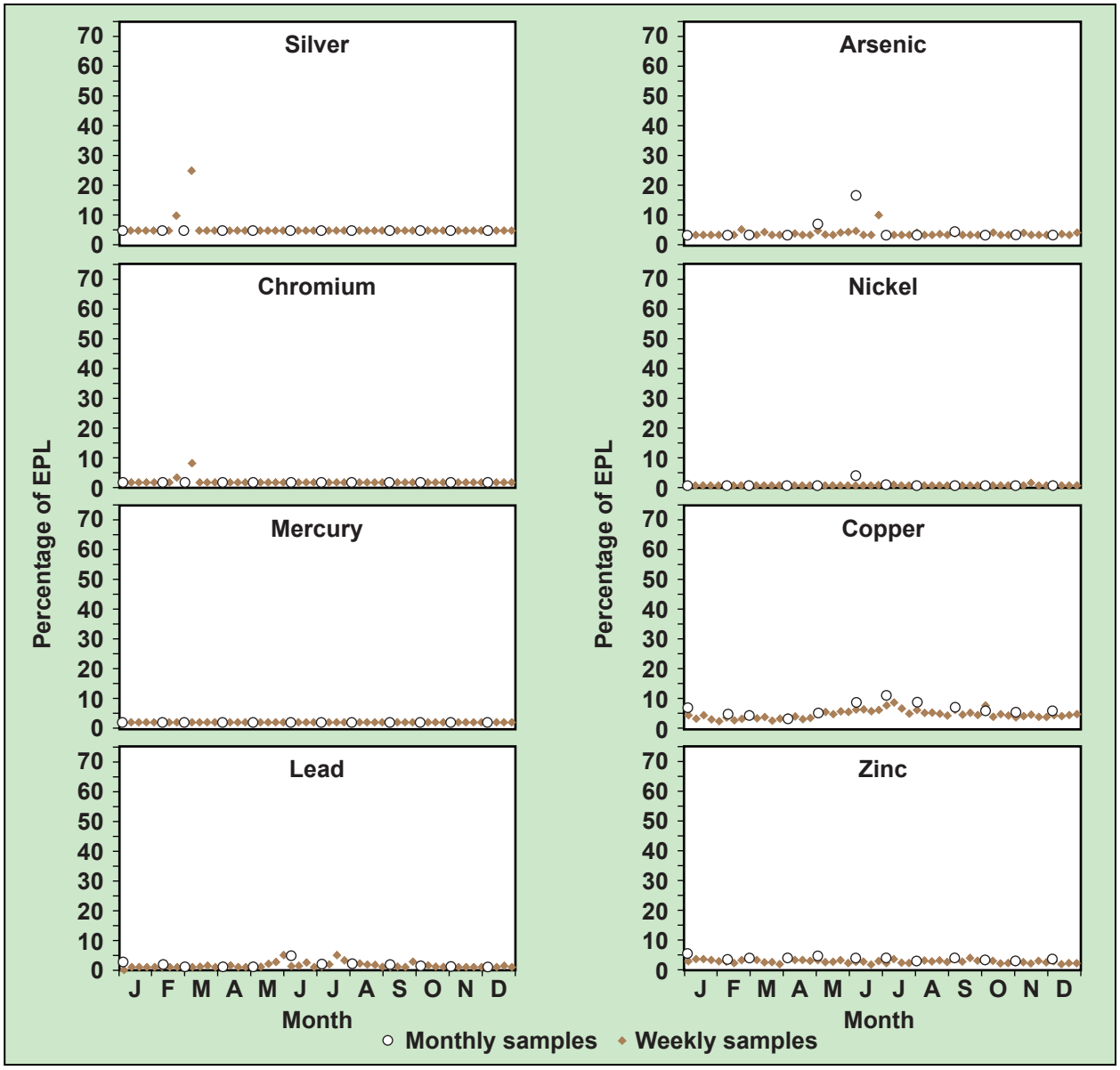


Figure 5-5. Results as percentages of effluent pollutant limits (EPLs) for eight of the nine regulated metals in LLNL sanitary sewer effluent, 2005

Detections of anions, metals, and organic compounds and summary data concerning other physical and chemical characteristics of the sanitary sewer effluent are provided in **Table 5-7**. (**Table 5-7** does not include the monthly metals results, which are plotted in **Figure 5-5**, or monthly monitoring results for analytes not detected in any of the 24-hour composite or grab samples. All analytical results are included in the file "Ch5 LV Wastewater" provided on the report CD.) The 2005 results are similar to typical values seen in previous years for the two regulated parameters, cyanide and total toxic organics (TTO; see chemicals with a "(e)" superscript in **Table 5-7**), and all other nonregulated parameters. Cyanide (permit limit 0.04 mg/L, sampled semiannually) was below analytical detection limits (0.02 mg/L) in the April sample and the October result (0.028 mg/L) was below the permit limit. The monthly TTO values ranged from 0.018 mg/L to 0.058 mg/L (with a TTO median value of 0.042 mg/L), well below the TTO permit limit of 1.0 mg/L. In addition to the organic compounds regulated under the TTO standard, five nonregulated organics were also detected in LLNL's sanitary sewer effluent: two volatile organic compounds (acetone and Freon 113) and three semi-volatile organic compounds (benzoic acid, benzyl alcohol, and 3- and 4-methylphenol [m- and p-Cresol]).

In 2005, the SMS continuous monitoring system detected a total of four inadvertent discharges outside the permitted pH range of 5 to 10. Two of these events, one with a pH below 5 and one with a pH above 10, were completely captured by the SDF. The other two events occurred off-hours when the upstream pH Monitoring Station (pHMS) was off-line. As a result, two front-end volumes (small quantity), of sanitary effluent outside the permitted pH range, were released to the LWRP system before a diversion to the SDF could be initiated. The first off-hours event (Saturday, March 5, 2005, at 0539) discharged approximately 200 gallons of pH 4.7 effluent to the LWRP, and another 1400 gallons were captured. The lowest pH recorded during the diversion was 4.4. The second off-hours event (Thursday, April 7, 2005, at 0503) discharged 300–600 gallons of pH 12 effluent to the LWRP, and another 1500 gallons were captured. The highest pH recorded during the diversion was 12.2. The LWRP was immediately notified of both these discharges; however, neither incident represented a threat to the integrity of the operations of the LWRP. The first event was not considered an enforceable exceedance of permit conditions. LLNL did receive a Notice of Violation (NOV) from the LWRP for exceeding the maximum pH limit of 10 in the April 7 release. (See Chapter 2.)

Table 5-7. Monthly monitoring summary for physical and chemical characteristics of the LLNL sanitary sewer effluent, 2005[a]

Parameter	Detection frequency[b]	Minimum	Maximum	Median	IQR[c]
24-hour composite sample parameter (mg/L)					
Alkalinity					
Bicarbonate alkalinity (as $CaCO_3$)	12 of 12	190	280	240	30.0
Carbonate alkalinity (as $CaCO_3$)	1 of 12	<5	14	<5	—[d]
Total alkalinity (as $CaCO_3$)	11 of 12	<2.5	280	235	32.5
Anions					
Bromide	11 of 12	<0.1	0.66	0.21	0.15
Chloride	12 of 12	41	66	52	11
Fluoride	11 of 12	<0.05	0.19	0.14	0.025
Orthophosphate	12 of 12	13	73	17	4.5
Sulfate	12 of 12	8	19	12	3.3
Nutrients					
Ammonia nitrogen (as N)	12 of 12	35	56	50	9.5
Total Kjeldahl nitrogen	12 of 12	49	100	59	7.0
Total phosphorus (as P)	12 of 12	6.5	29	7.7	0.95
Oxygen demand					
Biochemical oxygen demand	12 of 12	78	140	110	23.3
Chemical oxygen demand	12 of 12	190	280	225	40.0
Solids					
Settleable solids	1 of 12	<0.1	50	<0.1	—[d]
Total dissolved solids (TDS)	12 of 12	200	500	230	76.5
Total suspended solids (TSS)	12 of 12	55	480	67	31.0
Volatile solids	12 of 12	82	500	155	35.0
Total metals					
Aluminum	9 of 12	<0.2	<1	<0.18	—[d]
Calcium	12 of 12	9.4	17	12	1.3
Iron	12 of 12	0.46	1.1	0.55	0.10
Magnesium	12 of 12	2	3.9	2.2	0.65
Potassium	12 of 12	15	40	19	3.3
Sodium	12 of 12	33	56	40	9.0
Total organic carbon (TOC)	12 of 12	24	320	37	8.8
Grab sample parameter					
Semivolatile organic compounds (µg/L)					
1,2,4-Trichlorobenzene[e]	1 of 12	<2	<50	<5	—[d]
Benzoic acid	1 of 12	<10	<250	<25	—[d]
Benzyl alcohol	4 of 12	<10	<50	<10	—[d]
Bis(2-ethylhexyl)phthalate[e]	8 of 12	<5	<120	<13	—[d]
Butylbenzylphthalate[e]	1 of 12	<5	<50	<5	—[d]
Diethylphthalate[e]	10 of 12	<5	<50	<19	—[d]
Phenol[e]	5 of 12	<5	<50	<7.5	—[d]
m- and p-Cresol	4 of 12	<5	<50	<5	—[d]
Total cyanide (mg/L)[f]	1 of 2	<0.02	0.028	—[g]	—[d]
Total oil and grease (mg/L)[h]	7 of 8	<6.2	28	19.5	18.9

Table 5-7. Monthly monitoring summary for physical and chemical characteristics of the LLNL sanitary sewer effluent, 2005[a] (continued)

Parameter	Detection frequency[b]	Minimum	Maximum	Median	IQR[c]
Volatile organic compounds (µg/L)					
1,4-Dichlorobenzene[e]	4 of 12	<1	<1	<1	—[d]
Acetone	12 of 12	190	1800	410	260
Bromodichloromethane[e]	2 of 12	<0.5	<1	<0.5	—[d]
Chloroform[e]	12 of 12	7.7	17	12	4.3
Freon 113	1 of 12	<0.5	<1	<1	—[d]
Methylene chloride[e]	2 of 12	<1	8.3	<1	—[d]
Toluene[e]	6 of 12	<1	2.3	<1	—[d]

a The monthly sample results plotted in **Figure 5-5** and nondetected analytes are not included in this table.
b The number of times an analyte was positively identified, followed by the number of samples that were analyzed (generally 12, one sample for each month of the year).
c IQR = Interquartile range
d When the detection frequency is less than or equal to 50%, or there is no range, or there are fewer than six results for a sample parameter, the interquartile range is omitted.
e Priority toxic pollutant parameter used in assessing compliance with the total toxic organic (TTO) permit limit of 1 mg/L (1000 µg/L), LLNL Wastewater Discharge Permit 1250, 2004/2005, and 2005/2006.
f Sampling for this parameter is required on a semiannual (April and October) rather than a monthly basis.
g When there are fewer than four results for a sample parameter, the median is not calculated.
h The requirement to sample for oil and grease has been suspended until further notice per LWRP letter of April 1, 1999; nevertheless, LLNL collects these samples (four per day) semiannually as part of the source control program.

Categorical Processes

The U.S. Environmental Protection Agency (EPA) publishes Categorical standards for broad categories of specific industrial processes determined to be the most significant contributors to point-source water pollution. These standards contain specific numerical limits for the discharge of industry-specific pollutants from individual processes. At LLNL, the federal Categorical requirements are incorporated into the wastewater discharge permit (Permit 1250, 2004/2005 and 2005/2006), which is administered by the LWRP. The number of processes at LLNL under these standards is subject to periodic change as programmatic requirements dictate. During 2005, the LWRP identified 15 specific LLNL wastewater-generating processes that fall under the definition of two categorical standards: Electrical and Electronic Components (40 CFR 469), and Metal Finishing (40 CFR 433). Only those processes that discharge to the sanitary sewer require sampling, inspection, and reporting. Three of the 15 processes meet these criteria. In 2005, LLNL analyzed compliance samples for all regulated parameters from these three processes and demonstrated compliance with all federal Categorical discharge limits. Other processes that do not discharge to the sanitary sewer but would otherwise be regulated under the Metal-Finishing Point Source Category include printed circuit board manufacturing, electrolysis plating, chemical

etching, electroplating, anodizing, coating, electrical discharge machining, and abrasive jet machining. These 12 nondischarging processes are evaluated semiannually. Wastewater from these nondischarging processes is either recycled or contained for eventual removal and appropriate disposal by LLNL's RHWM Division. Because these processes do not discharge directly or indirectly to the sanitary sewer, they are not subject to the monitoring and reporting requirements contained in the applicable standard. See *Lawrence Livermore National Laboratory, Livermore Site Semiannual Wastewater Point-Source Monitoring Reports for (December 2004–May 2005) and June 1–November 30, 2005)* (Grayson 2005a,b).

As required in LLNL's Wastewater Discharge Permit, compliance with Permit requirements is demonstrated by semiannual sampling and reporting. LWRP Source Control staff performed the required annual inspection and sampling of the three discharging categorical processes in 2005. The three processes sampled are 1) the Building 153 retention tank (for wastewater from various semiconductor processes [wafer cleaning/etching and photolithography]), 2) gallium arsenide saw cutting in Building 153, and 3) the Building 321C abrasive jet machining. LLNL Environmental staff sample the same processes semiannually. These compliance samples were analyzed for all regulated parameters and the resulting data collected demonstrate compliance with all federal and local pretreatment limits. Of the three discharging categorical processes, the Building 153 microfabrication facility released the largest volume of water to the sanitary sewer. As a further environmental safeguard, LLNL sampled each volume retained at Building 153 prior to discharge to the sanitary sewer. These monitoring data were reported to the LWRP in July 2005 and January 2006 semiannual wastewater reports (Grayson 2005, 2006).

Discharges of Treated Groundwater

LLNL's groundwater discharge permit (1510G, 2004-2006) allows treated groundwater from the Livermore site Ground Water Project (GWP) to be discharged in the City of Livermore sanitary sewer system. (See Chapter 8 for more information on the GWP.) During 2005, there were two discharges to the sanitary sewer from the GWP. The total volume of treated groundwater discharged to the sanitary sewer was 2560 liters. In each of these discharge events, the groundwater released to the sanitary sewer originated from the lower zone, beneath the LLNL site. These volumes of groundwater were acquired at one of the on-site treatment facilities and used to condition new ion exchange resin columns. These two events were separately sampled and discharged to the sanitary sewer during 2005, all in compliance with self-monitoring permit provisions and discharge limits of the permit. Complete monitoring data are presented in the *Ground Water Discharge Annual Self-Monitoring Report for 2005* (Revelli 2006a).

Environmental Impact of Sanitary Sewer Effluent

During 2005, no discharges exceeded any discharge limits for release of radioactive materials to the sanitary sewer. The data are comparable to the lowest historical values. All the values reported for radiological releases are a fraction of their corresponding limits. For nonradiological releases, LLNL achieved near perfect compliance with the provisions of its wastewater discharge permit; there were only two releases of pH outside permissible limits.

The data demonstrate that LLNL continues to have good control of radiological and nonradiological discharges to the sanitary sewer. Monitoring results for 2005 reflect an effective year for LLNL's wastewater discharge control program and indicate no adverse impact to the LWRP or the environment from LLNL sanitary sewer discharges.

Site 300 Sewage Ponds and Surface Impoundments

Wastewater samples collected from the influent to the sewage evaporation pond, within the sewage evaporation pond, and flow to the sewage percolation pond; and wastewater samples collected from discharges to the Class II surface impoundments from photographic processes, Chemistry Area processes, and Explosives processes were obtained in accordance with the written standardized procedures summarized in the *Environmental Monitoring Plan* (Woods 2005).

Sewage Evaporation and Percolation Ponds

Sewage generated at buildings in the General Services Area at Site 300 is discharged into a lined evaporation pond. The nonhazardous wastewater is disposed of through evaporation from the pond. However, during winter rains, treated wastewater may overflow into an unlined percolation pond, where it enters the ground and the shallow groundwater.

The environmental monitoring requirements for the sewage evaporation and percolation ponds (hereafter collectively referred to as sewage ponds) are specified in the Monitoring and Reporting Program (MRP) for Waste Discharge Requirements Order No. 96-248 (WDR 96-248). The monitoring requirements include both wastewater monitoring and groundwater monitoring to detect potential impacts of the sewage on groundwater quality. Wastewater is sampled quarterly at a sampling point (ISWP) in the line running into the sewage pond and within the sewage evaporation pond (ESWP). Overflows into the adjacent percolation pond are also permitted

under WDR 96-248 and are sampled as needed in the discharge line (DSWP) from the sewage pond to the percolation pond. Nine groundwater monitoring wells are sampled semiannually to provide information on the groundwater quality in the vicinity of the sewage ponds. All sampling locations are shown in **Figure 5-6**. The wells are screened in three different geological formations: Qal, $Tnbs_1$, and $Tnsc_1$ (see Chapter 8). $Tnbs_1$ (Neroly Formation lower blue sandstone unit) is the regional aquifer.

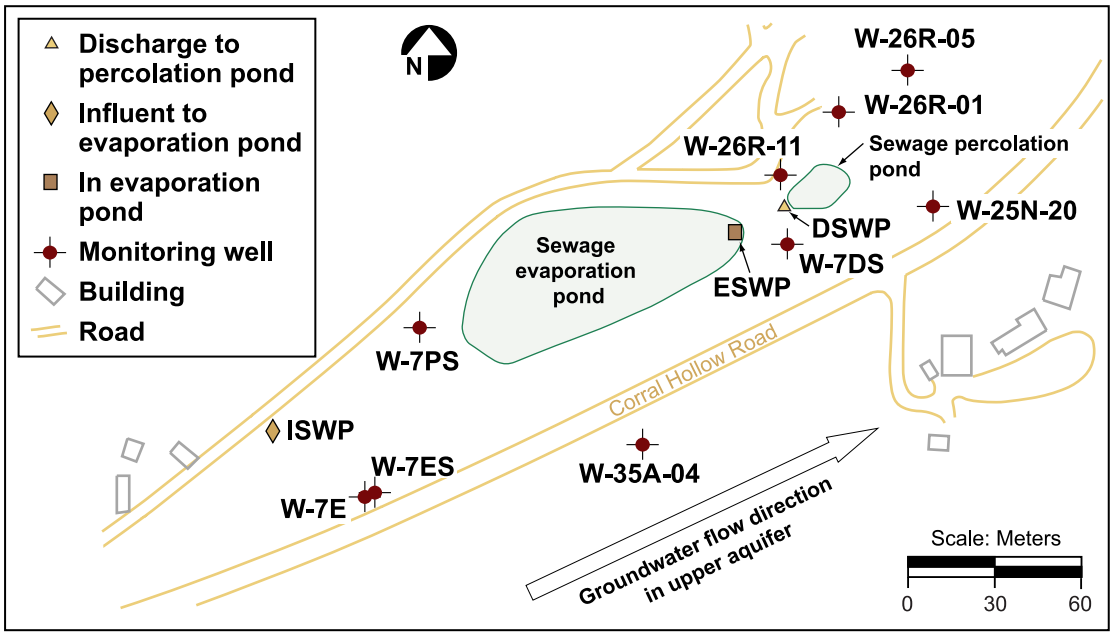


Figure 5-6. Sewage evaporation and percolation ponds, compliance groundwater monitoring wells, and wastewater monitoring locations, 2005

All wastewater parameters for the sewage evaporation and percolation ponds complied with permit provisions and specifications throughout 2005. There was one continuous overflow from the sewage evaporation pond to the percolation pond that began in January 2005 and continued through the first quarter of 2005. This permitted discharge was sampled twice and reported to the Central Valley Regional Water Quality Control Board (CVRWQCB). In two instances during the first quarter, in samples collected from wells W-35A-04 and W-26R-11, the concentrations of the monitored groundwater constituent fecal coliform bacteria exceeded the permit limit. Those concentrations, however, were not confirmed by subsequent sample results and fecal coliform bacteria have not been detected in any subsequent groundwater samples. For details, see *LLNL Experimental Test Site 300 Compliance Monitoring Report for Waste Discharge Requirements 96-248, Annual/Fourth Quarter Report 2005* (Brown 2006).

Surface Impoundments

WDR 96-248 also establishes the basis for compliance monitoring of two connected surface impoundments at Site 300 that receive nonhazardous wastewater and rinsewater discharges from the Explosives Process Area, chemistry buildings, and photographic processes. This includes monitoring of various influent waste streams to the surface impoundments. Influent monitoring complements administrative control of chemicals that could degrade the polyethylene liners of the impoundments. A two-tiered monitoring program comprising weekly visual inspections of the leachate collection and removal systems, and quarterly sampling of monitoring wells was in place to detect any release of chemicals from the surface impoundments.

LLNL completed clean closure of the two Class II surface impoundments in November 2005. In anticipation of the closure and demolition, wastewater discharges to the impoundments were discontinued by June 2005. Monitoring of wastewater continued until discharges ceased, and monitoring of the leachate collection system continued until the impoundments were demolished. The nonhazardous wastewater is now managed in retention tanks where it is allowed to evaporate or, if necessary, it is transported to the Livermore site for disposal to the sanitary sewer. Groundwater monitoring continued through the end of 2005 and was discontinued when the CVRWQCB modified the monitoring and reporting program associated with WDR 96-248.

Wastewater discharges from each of these three processes (explosives, chemistry, and photography) to the surface impoundments were analyzed for constituents of concern (COCs) that have been found, or were likely to be found, in the process water from each specified process area. The monitoring program contained in WDR 96-248 established limits for discharges of COCs into the surface impoundments. In addition, no hazardous or radioactive waste was allowed in the surface impoundments.

Influent waste streams were monitored at a prescribed frequency for area-specific COCs. Annual monitoring was performed on discharges from the Explosives Process Area: Buildings 806/807 and 817. (Building 809 is also included in this area but was inactive in 2005.) Discharges from this area flowed automatically into the surface impoundments. Wastewater from the Chemistry Area (Buildings 825 and 826, and the Building 827 Complex) was held in retention tanks until analytical results indicated that all COCs were within discharge limits. No discharges occurred from the retention tanks at Buildings 825, 826, or 827A; two discharges from Buildings 827C, 827D, and 827E to the surface impoundments occurred in the second quarter of 2005. Rinsewater from photographic processes at Building 823 was discharged automatically to the surface impoundments through the second quarter of

2005. Samples from Building 823 discharges were collected in the first and second quarters and analyzed to satisfy the requirements of WDR 96-248.

No release of water to ground from the surface impoundments occurred during 2005. For a detailed account of compliance monitoring of the Site 300 surface impoundments, see *LLNL Experimental Test Site 300 Compliance Monitoring Report for Waste Discharge Requirements 96-248, Annual/Fourth Quarter Report 2005 (Brown 2006)*.

The two leachate collection and removal systems were monitored weekly for the presence of liquids to identify potential leaks. None were observed during 2005. No water has been observed in the leachate collection and removal system since liner repairs were made in 1997.

In the Explosives Process Area, LLNL is required to obtain groundwater samples quarterly from four monitoring wells (see **Figure 5-7**) and has established statistical concentration limits for COCs in groundwater beneath the surface impoundments. These requirements are part of the MRP for the surface impoundments detailed in WDR 96-248. Sporadic detections of ammonia and of the plasticizer compound bis(2-ethylhexyl)phthalate (DEHP) have occurred since 2000. However, because these chemicals have also been detected in method blank samples, LLNL has determined that these COCs were not present in the groundwater samples but were due to laboratory contamination of the samples.

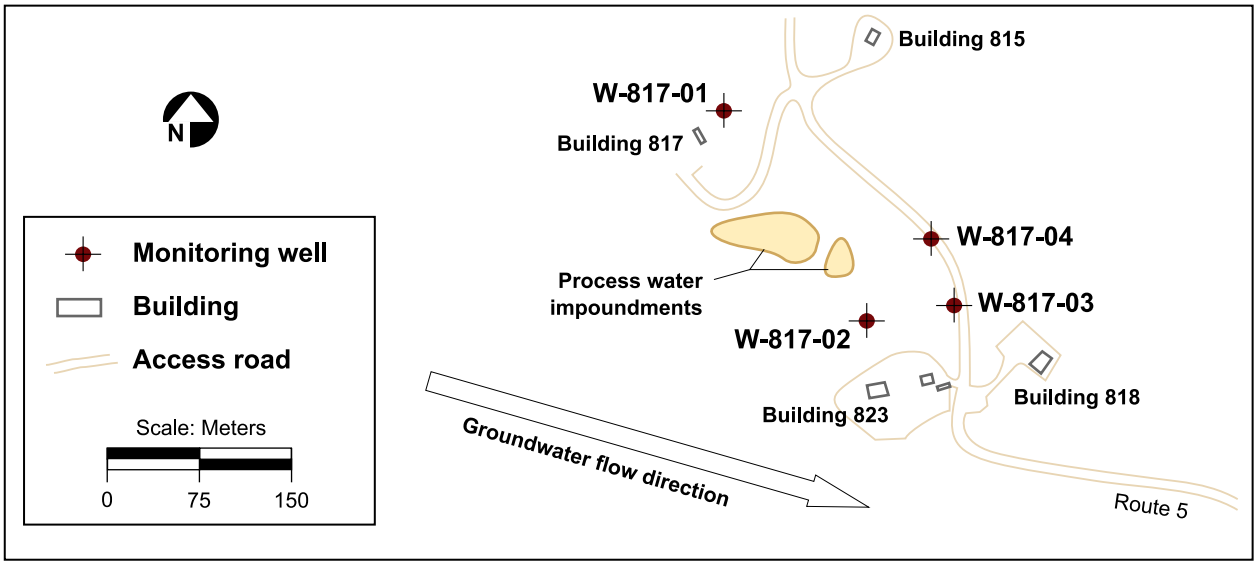


Figure 5-7. Locations of compliance groundwater monitoring wells in the Explosives Process Area, 2005

Explosive compounds (HMX, RDX, and breakdown products) and perchlorate are the compounds most indicative of discharges to groundwater from the Explosives Process Area surface impoundments. However, prior to 1985, explosives wastewater was discharged into unlined ponds in the vicinity of the present surface impoundments where it infiltrated the soil; some of the explosives wastewater reached groundwater. Because of this past practice, it is necessary under regulations to discriminate between new releases from the surface impoundments and past releases from the unlined ponds. Background concentrations were statistically calculated for each COC based on historical data from all four monitoring wells. Any sample concentration exceeding background concentrations, and confirmed by either of two retest sample concentrations exceeding background concentrations, is assumed to come from a new release of that COC. (See also Chapter 8.) A few concentrations of the energetic compounds PETN, RDX, and 4-amino-2,6-dinitrotoluene that exceeded statistical limits in downgradient monitor wells during the second, third, and fourth quarters were determined to be statistical outliers. As statistical outliers, it was not necessary to report them to the CVRWQCB as exceeding statistical limits. No concentrations exceeding the statistical limits were confirmed by two retest samples collected and analyzed one week apart from each of those wells. LLNL continues to monitor and to track these concentrations. For details, see *LLNL Experimental Test Site 300 Compliance Monitoring Report for Waste Discharge Requirements 96-248, Annual/Fourth Quarter Report 2005* (Brown 2006).

Percolation Pits

Percolation pits designed to accept discharges from mechanical equipment are located at Site 300 Buildings 806A, 827A, 827C, 827D, and 827E. These discharges are permitted by WDR 96-248, which specifies monthly observations and monitoring requirements for overflows of the percolation pits. In other Site 300 facilities, these types of waste streams are discharged to septic systems. If an overflow should occur, it is sampled and analyzed to determine concentrations of any metals present. During 2005, all of the percolation pits operated normally with no overflows. Percolation pits at Buildings 827C and 827D contained standing water throughout the fourth quarter (Brown 2006).

Environmental Impact of Sewage Ponds and Surface Impoundments

All discharges from the Site 300 sewage evaporation pond to the percolation pond, as well as discharges to the surface impoundments from the Explosives Process Area, chemistry buildings, and photographic processes were in

compliance with discharge limits. Groundwater monitoring related to these areas indicates that there were no measurable impacts to the groundwater from the surface impoundment operations. There were sporadic detections of coliform bacteria in groundwater samples collected from two wells surrounding the sewage ponds early in 2005, but those detections were not validated by subsequent sampling and analysis. (Brown 2006)

Storm Water Compliance and Surveillance Monitoring

To assess compliance with permit requirements, LLNL monitors storm water at the Livermore site in accordance with WDR 95-174, National Pollutant Discharge Elimination System (NPDES) Permit No. CA0030023, issued in 1995 by the San Francisco Bay Regional Water Quality Control Board (SFBRWQCB 1995a). LLNL monitors storm water discharges at Site 300 in accordance with the California NPDES General Permit for Storm Water Discharges Associated with Industrial Activity (WDR 97-03-DWQ), NPDES Permit No. CAS000001, State Water Resources Control Board (SWRCB 1997). For construction projects that disturb 0.4 hectares (1 acre) of land or more LLNL also meets storm water compliance monitoring requirements of the California NPDES General Permit for Storm Water Discharges Associated with Construction Activity (WDR 99-08-DWQ, NPDES Permit No. CAS000002) (SWRCB 1999) and subsequent modifications.

Site 300 storm water monitoring also meets the requirements of the *Post-Closure Plan for the Pit 6 Landfill Operable Unit* (Ferry et al. 1998). In addition to the storm water quality constituents required by the closure plan, LLNL monitors other constituents to provide a more complete water quality profile. Appendix A includes the current list of analyses conducted on storm water, including analytical methods and typical reporting limits.

Storm water monitoring at both sites also follows the requirements in the *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (U.S. DOE 1991) and meets the applicable requirements of DOE Order 5400.5, Radiation Protection of the Public and the Environment.

At all monitoring locations at both the Livermore site and Site 300, grab samples are collected from the storm water runoff flowing in the storm drains and stream channels. Grab samples are collected by partially submerging sample bottles directly into the water and allowing them to fill with the sample water. If the water to be sampled is not directly accessible, an automatic water sampler is used to pump water into the appropriate containers. Sampling is conducted away from the edge of the arroyo to

prevent the collection of sediment into the water samples. Sample vials for volatile organics are filled before sample bottles for all other constituents and parameters.

For the purpose of evaluating the overall impact of the Livermore site and Site 300 operations on storm water quality, storm water flows are sampled at upstream and downstream locations. Because of flow patterns at the Livermore site, storm water at sampling locations includes runoff from other sources, such as neighboring agricultural land, parking lots, and landscaped areas. In contrast, storm water at Site 300 is sampled at locations that target specific on-site activities with no run-on from off-site sources. These samples provide the information necessary to maintain compliance with the SWRCB.

NPDES permits for storm water require that LLNL sample effluent two times per year. In addition, LLNL is required to visually inspect the storm drainage system during one storm event per month in the wet season (defined as October of one year through April [Livermore site] or May [Site 300] of the following year) to observe runoff quality and twice during the dry season to identify any dry weather flows. Influent sampling is also required at the Livermore site. In addition, annual facility inspections are required to ensure that the best management practices (BMPs) to control storm water pollution are implemented and adequate.

Constituent Criteria

There are no numeric criteria that limit concentrations of specific constituents in LLNL's storm water effluent. The U.S. Environmental Protection Agency (EPA) established parameter benchmark values, but stressed that these concentrations are not intended to be interpreted as effluent limits (U.S. EPA 2000). Rather, the values are levels that the EPA has used to determine if storm water discharged from any given facility merits further monitoring. Although these criteria are not directly applicable, they are used as comparison criteria to help LLNL evaluate its storm water management program. To further evaluate the storm water management program, LLNL established or calculated site-specific threshold comparison criteria for a select group of parameters. A value exceeds the threshold if it is greater than the 95% confidence limit computed for the historical mean value for a specific parameter (**Table 5-8**). The threshold comparison criteria are used to identify out-of-the-ordinary data that merit further investigation to determine if concentrations of that parameter are increasing in the storm water runoff. For a better understanding of how LLNL storm water data relate to other target values, LLNL also compares water samples with criteria listed in the *Water Quality Control Plan, San Francisco Bay Basin* (SFBRWQCB 1995b), *The Water Quality Control Plan (Basin Plan) for the California Regional Water Quality Control Board, Central Valley Region, Sacramento and San Joaquin*

River Basins (CVRWQCB 1998b), state and federal maximum contaminant levels (MCLs), and U.S. EPA ambient water quality criteria (AWQC). The greatest importance is placed on the site-specific comparison criteria calculated from historical concentrations in storm runoff.

Table 5-8. Threshold comparison criteria for selected water quality parameters

Parameter	Livermore site	Site 300
Total suspended solids (TSS)	750 mg/L[a]	1,700 mg/L[a]
Chemical oxygen demand (COD)	200 mg/L[a]	200 mg/L[a]
pH	<6.0, >8.5[a]	<6.0, >9.0[b]
Nitrate (as NO_3)	10 mg/L[a]	not monitored
Orthophosphate	2.5 mg/L[a]	not monitored
Beryllium	1.6 µg/L[a]	1.6 µg/L[a]
Chromium(VI)	15 µg/L[a]	not monitored
Copper	13 µg/L[c]	not monitored
Lead	15 µg/L[d]	30 µg/L[a]
Zinc	350 µg/L[a]	not monitored
Mercury	above RL[e]	1 µg/L[a]
Diuron	14 µg/L[a]	not monitored
Oil and grease	9 mg/L[a]	9 mg/L[a]
Tritium	36 Bq/L[a]	3.17 Bq/L[a]
Gross alpha radioactivity	0.34 Bq/L[a]	0.90 Bq/L[a]
Gross beta radioactivity	0.48 Bq/L[a]	1.73 Bq/L[a]

Note: If data exceed the threshold comparison criteria, an investigation is initiated to assess if those data are indicative of a water quality problem.

a Site-specific value calculated from historical data and studies. These values are lower than the MCLs and EPA benchmarks except for zinc, TSS, and COD.

b EPA benchmark

c Ambient water quality criteria (AWQC)

d California and EPA drinking water action level

e RL = reporting limit = 0.0002 mg/L for mercury

Storm Water Inspections

Each directorate at LLNL conducts an annual inspection of its facilities to verify implementation of the storm water pollution prevention plans (SWPPPs) and to ensure that measures to reduce pollutant discharges to storm water runoff are adequate. LLNL's associate directors certified in 2005 that their facilities complied with the provisions of LLNL's storm water pollution prevention plans. LLNL submits annual storm water monitoring reports to the SFBRWQCB (Brown 2005b) and to the CVRWQCB (Brown 2005a) with the results of sampling, observations, and inspections.

For each construction project permitted by WDR 99-08-DWQ, LLNL conducts visual monitoring of construction sites before, during, and after storms to assess the effectiveness of BMPs. Annual compliance certifications summarize these inspections. Annual compliance certifications for 2005 covered the period of June 2004 through May 2005. When requested by the respective regional water quality control board (RWQCB), LLNL completes annual compliance status reports that cover the same reporting period. During the 2004/2005 reporting period, LLNL had active permits for six projects located at the Livermore site and two at Site 300 (see **Table 2-3**). Three of the projects that commenced in 2005 were completed during the reporting period: Arroyo Seco Management Plan, Surface Impoundment Closure and Tanks Installation, and the Mid Elk Ravine California red-legged Frog Project. LLNL terminated the permits for these three projects and for one multi-year project (the Terascale Simulation Project) that was completed during 2005

Livermore Site

As is commonly the case in urbanized areas, surface water bodies and runoff pathways at LLNL do not represent natural conditions. The drainage at the Livermore site was altered by construction activities several times up to 1966 (Thorpe et al. 1990) so that the current northwest flow of Arroyo Seco and the westward flow of Arroyo Las Positas do not represent historical flow paths. About 1.6 km to the west of the Livermore site, Arroyo Seco merges with Arroyo Las Positas, which continues to the west to eventually merge with Arroyo Mocho (see **Figure 5-8**).

The Drainage Retention Basin (DRB) was excavated and lined in 1992 to prevent infiltration of storm water that was dispersing groundwater contaminants. It also serves storm water diversion and flood control purposes. The DRB collects less than one-fourth of the surface water runoff from the site and a portion of the Arroyo Las Positas drainage (**Figure 5-9**). When full, the DRB discharges north to a culvert that leads to Arroyo Las Positas. The remainder of the site drains either directly or indirectly into the two arroyos by way of storm drains and swales. Arroyo Seco cuts across the southwestern corner of the site. Arroyo Las Positas follows the north-eastern and northern boundaries of the site and exits the site near the northwest corner.

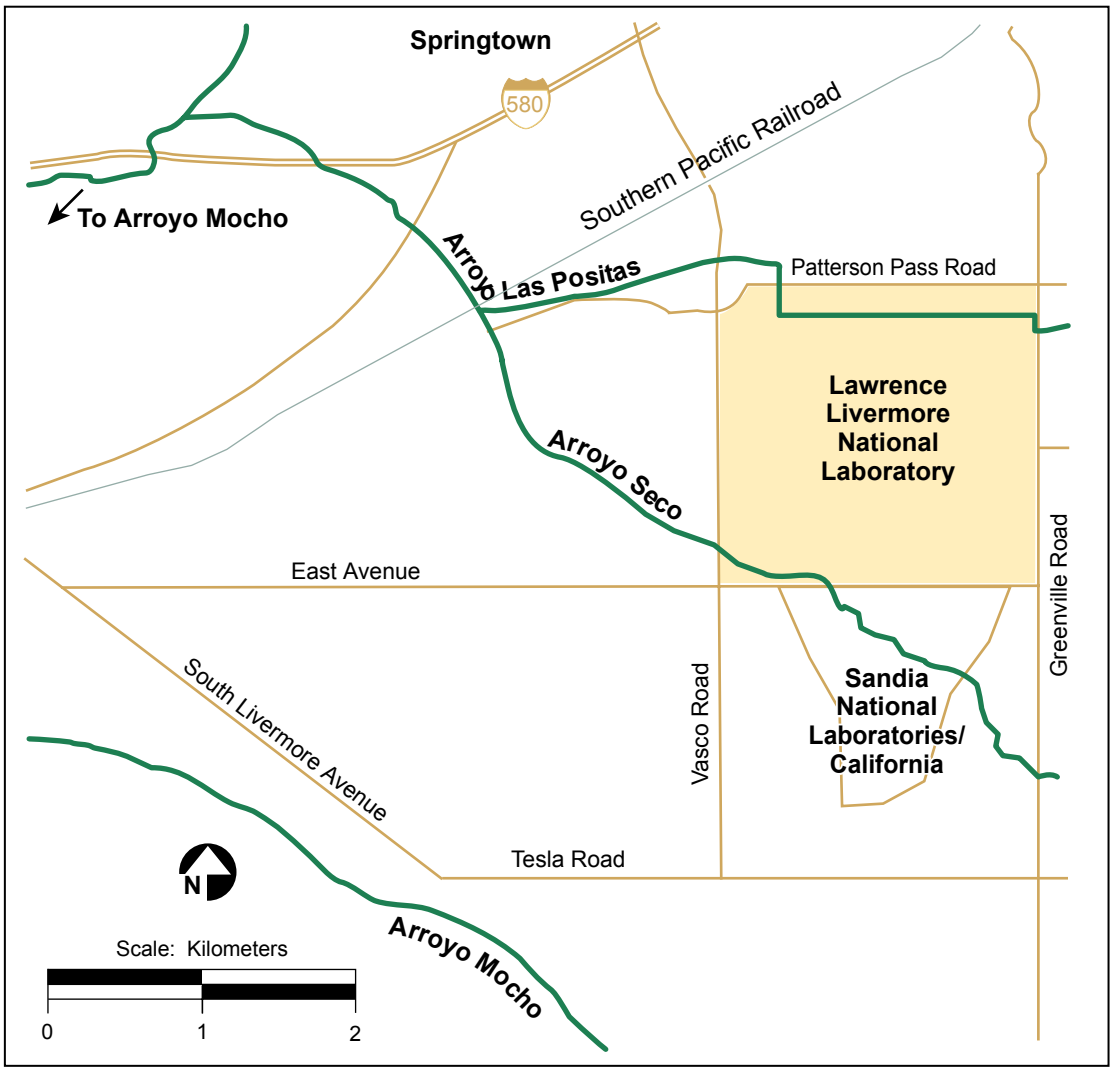


Figure 5-8. Surface waterways in the vicinity of the Livermore site

The routine Livermore site storm water runoff monitoring network consists of nine sampling locations (**Figure 5-9**). Six locations characterize storm water either entering (influent: ALPE, ALPO, ASS2, and GRNE) or exiting (effluent: ASW and WPDC) the Livermore site. Sampling locations CDB and CDBW are internal sites used by LLNL staff, outside the requirements of the storm water permit, to characterize storm water runoff quality entering the DRB; location CDBX characterizes water leaving the DRB. LLNL collected samples at all nine locations on January 11 and February 16, 2005.

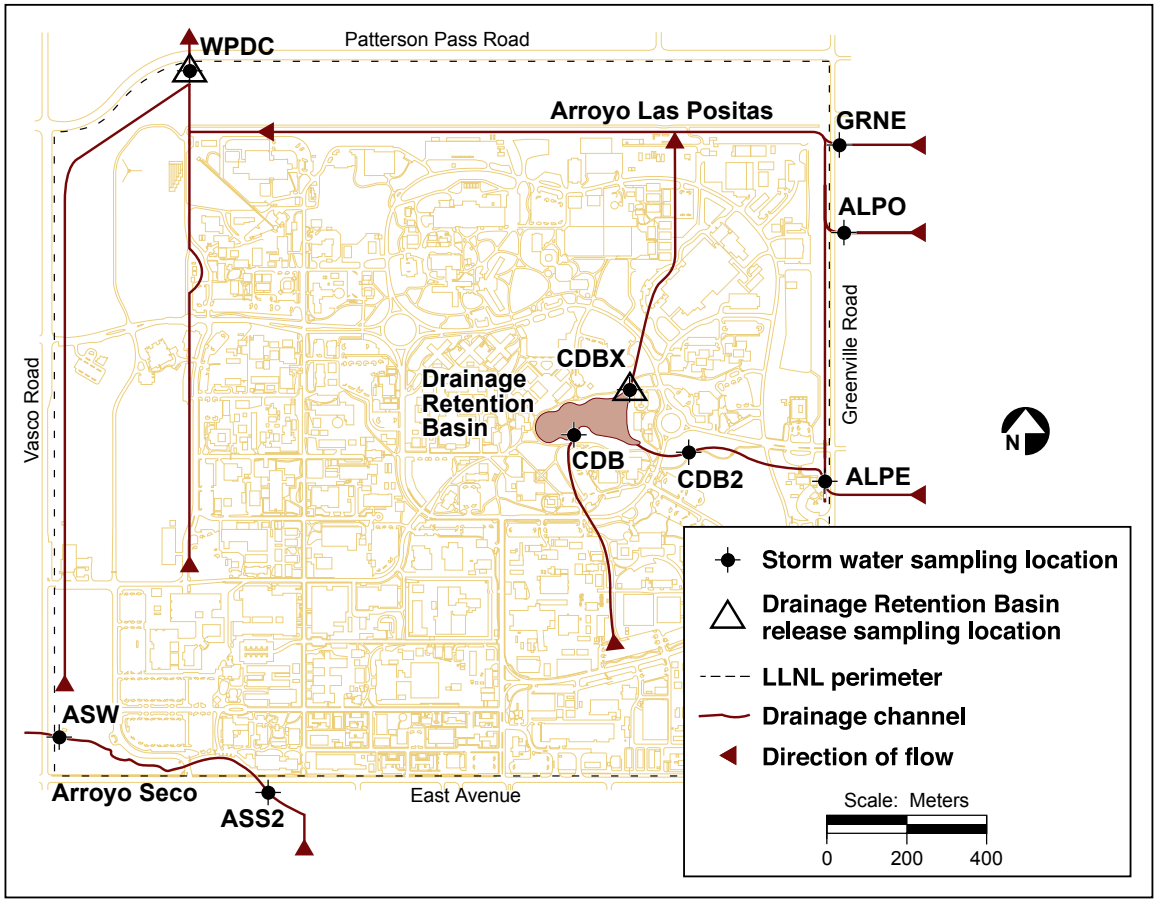


Figure 5-9. Storm water runoff and Drainage Retention Basin sampling locations, Livermore site, 2005

Acute and chronic toxicity testing using fathead minnows (*Pimephales promelas*) was not performed during the 2005 calendar year for WDR 95-174. Toxicity tests for WDR 95-174 are performed using water sampled from the first major runoff event occurring during normal work hours (8:00 am–5:00 pm). This runoff event did not take place in 2005, but in January 2006. However, toxicity testing was performed during 2005 for DRB releases (see the section "Drainage Retention Basin Release" in this chapter).

Radiological Monitoring Results

Storm water sampling and analysis were performed for gross alpha, gross beta, plutonium, and tritium. Storm water gross alpha, gross beta, and tritium results are summarized in **Table 5-9**. (Complete analytical results are included in the file "Ch5 Storm Water" provided on the report CD.) Tritium activities at site effluent sampling locations were less than 1% of the MCL. Gross alpha and gross beta radioactivity in the storm water samples collected during 2005 were generally low, with medians around background

levels. Gross beta activities exceeded LLNL-specific comparison criteria on February 16, 2005, in water samples collected at effluent location ASW along the Arroyo Seco. However, gross beta activities in samples collected from the influent location ASS2 (where runoff flows onto the Livermore site) were also above the comparison criteria (**Table 5-10**). The difference between the influent and effluent locations is statistically insignificant. Therefore, this result was unlikely to be related to LLNL activities.

Table 5-9. Statistics on radioactivity in storm water from the Livermore site, 2005[a]

Parameters	Tritium (Bq/L)	Gross Alpha (Bq/L)	Gross Beta (Bq/L)
MCL	740	0.555	1.85
Influent			
Median	1.26	0.022	0.169
Minimum	–0.41	–0.004	0.062
Maximum	6.0	0.146	0.622
Effluent			
Median	1.1	0.022	0.096
Minimum	0.2	0.013	0.084
Maximum	4.3	0.219	0.685

a See Chapter 9 for an explanation of calculated values.

Table 5-10. Water quality parameters in storm water runoff above LLNL-specific threshold comparison criteria, Livermore site in 2005

Parameter	Date	Location	Influent or Effluent	Result (mg/L)	LLNL threshold criteria (mg/L)
Nonradioactive (mg/L)					
Copper	1/11	ALPE	Influent	0.015	0.013
	1/11	ALPO	Influent	0.019	0.013
	2/16	ASW	Effluent	0.020	0.013
	2/16	ASS2	Influent	0.019	0.013
	2/16	ALPO	Influent	0.015	0.013
		Radioactive (Bq/L)			
Gross beta	2/16	ASW	Effluent	0.68 ± 0.11	0.48
	2/16	ASS2	Influent	0.62 ± 0.10	0.48

LLNL began analyzing for plutonium in storm water in 1998. Current storm water sampling locations for plutonium are the Arroyo Seco and the Arroyo Las Positas effluent locations (ASW and WPDC). In 2005, there were no plutonium results above the detection limit of 0.0037 Bq/L (0.10 pCi/L).

Nonradiological Monitoring Results

In addition to radioactivity, storm water was analyzed for other water quality parameters. Sample results were compared with the comparison criteria in **Table 5-8**. Of interest are the constituents that exceed comparison criteria at effluent points and whose concentrations are lower in influent than in effluent. If influent concentrations are higher than effluent concentrations, the source is generally assumed to be unrelated to LLNL operations and LLNL conducts no further investigation. (Complete analytical results are included in the file "Ch5 Storm Water" provided on the report CD.) Constituents that exceeded comparison criteria for effluent and/or influent locations are listed in **Table 5-10**. All of the values above threshold comparison criteria for the Livermore site during 2005 were found at influent tributaries at similar concentrations. Copper concentrations in samples collected from runoff exceeded LLNL's threshold comparison criteria on both sampling dates at influent locations and at one effluent location (ASW) on February 16, 2005. In this latter instance, the concentration of copper in samples collected from influent location ASS2 were similarly elevated, so it is concluded that these results are unrelated to LLNL discharges.

Site 300

Surface water at Site 300 consists of seasonal runoff, springs, and natural and man-made ponds. The primary waterway in the Site 300 area is Corral Hollow Creek, an ephemeral stream that borders the site to the south and southeast. No natural continuously flowing streams are present in the Site 300 area. Elk Ravine is the major drainage for most of Site 300; it extends from the northwest portion of the site to the east–central area. Elk Ravine drains the center of the site into Corral Hollow Creek, which drains eastward toward the San Joaquin River Basin. Some smaller canyons in the northeast portion of the site drain to the north and east toward Tracy.

There are at least 23 springs at Site 300. Nineteen are perennial, and four are intermittent. Most of the springs have very low flow rates and are recognized only by small marshy areas, pools of water, or vegetation. Several artificial surface water bodies at Site 300 are in fact wastewater treatment units discussed above. Three wetlands created by now-discontinued flows from cooling towers located at Buildings 827, 851, and 865 were maintained in 2005 by discharges of potable water.

In 2005, storm water runoff was characterized at five sampling locations that could be affected by specific Site 300 activities. In addition, off-site location CARW2 is used to characterize Corral Hollow Creek upstream and, therefore, is unaffected by Site 300 industrial storm water discharges. Off-site location

GEOCRK is used to characterize Corral Hollow Creek downstream of Site 300. These locations are shown in **Figure 5-10**.

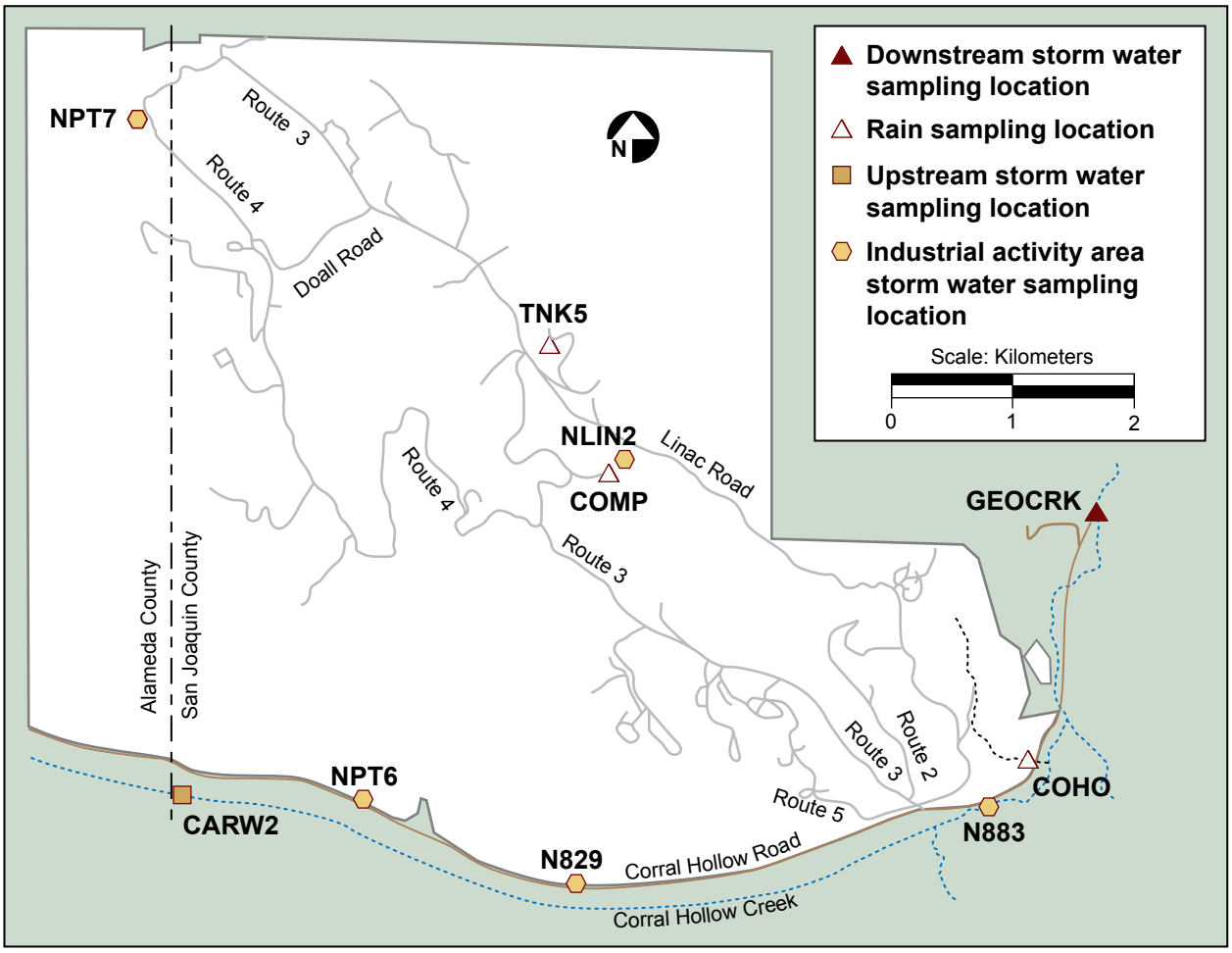


Figure 5-10. Storm water and rainwater sampling locations at Site 300, 2005

The Site 300 storm water permit specifies sampling a minimum of two storms per rainy season. Typically, a single storm does not produce runoff at all Site 300 locations because Site 300 receives relatively little rainfall and is largely undeveloped with few paved areas. Therefore, at many locations, a series of large storms is required to saturate the ground before runoff can occur. At some of the sampling locations in some years, there is not enough rain to generate runoff over an entire rainy season. On January 26 and February 15, storm water samples were collected and analyzed from all locations that normally have storm water flow.

Radiological Monitoring Results

Storm water sampling and analysis was performed for gross alpha and gross beta radioactivity, uranium isotopes, and tritium, and results were compared

with the comparison criteria in Table 5-8. (Complete analytical results are included in the file "Ch5 Storm Water" provided on the report CD.) Concentrations of gross alpha or beta radioactivity exceeding Site 300's threshold concentrations are reported in Table 5-11. Tritium concentrations at all sampled locations were less than 1% of the MCL and less than Site 300's threshold concentration. Gross alpha and gross beta radioactivity in the storm water samples collected from upstream location CARW2 and from downstream location GEOCRK on February 15 exceeded LLNL's site-specific criteria. Those samples were associated with higher than normal TSS and lead concentrations. Previous environmental sampling has shown that suspended sediments from this area contain significant quantities of naturally occurring uranium and its daughter decay products, and sometimes other metals, that account for the elevated gross alpha and beta radioactivity.

Table 5-11. Water quality parameters in storm water runoff above LLNL-specific threshold comparison criteria, Site 300, 2005

Parameter	Date	Location	Upstream or Downstream	Result	Threshold criteria
Radioactive (Bq/L)					
Gross alpha[b]	2/15	CARW2	Upstream	2.4 ± 0.7	0.90
	2/15	GEOCRK	Downstream	2.2 ± 0.7	0.90
Gross beta[b]	2/15	CARW2	Upstream	3.5 ± 0.7	1.73
	2/15	GEOCRK	Downstream	4.5 ± 0.7	1.73
Nonradioactive (mg/L)					
Total suspended solids	2/15	CARW2	Upstream	3400	1700
	2/15	GEOCRK	Downstream	3800	1700
Lead[a]	2/15	CARW2	Upstream	0.050	0.030
	2/15	GEOCRK	Downstream	0.079	0.030
Chemical oxygen demand	2/15	GEOCRK	Downstream	288	200

a Total metals including particulates
b Total radiation including particulates

Nonradiological Monitoring Results

Site 300 storm water samples were analyzed for nonradiological water quality parameters, and sample results were compared with the comparison criteria in Table 5-8. Constituents that exceeded comparison criteria for upstream and downstream locations are listed in Table 5-11. During 2005 constituent concentrations of TSS (3800 mg/L), lead (0.079 mg/L), and chemical oxygen demand (288 mg/L) exceeded comparison criteria at GEOCRK. High TSS concentrations are not unusual in large storms generating runoff in Elk Ravine. Concentrations of TSS (3400 mg/L) and lead (0.050 mg/L) in storm water samples collected from upstream location CARW2 on February 15 also exceeded their site-specific criteria for those

parameters. (Complete analytical results are included in the file "Ch5 Storm Water" provided on the report CD.)

Because of a Comprehensive Environmental Response Compensation Liability Act (CERCLA) remedial investigation finding of past releases of dioxins and polychlorinated biphenyls (PCBs) related to activities in the vicinity of Building 850, analysis for these compounds was conducted on runoff samples collected on January 26 from both locations NLIN2, the sampling location downstream from Building 850, and GEOCRK and on February 15 from location GEOCRK only. The intent of the sampling was to determine whether these constituents are being released down Elk Ravine and, eventually, off site in storm water runoff. (Complete analytical results are included in the file "Ch5 Storm Water" provided on the report CD.) No PCBs were detected in those samples. All dioxins detected were below the equivalent federal MCL of 30 pg/L.

The federal MCL for dioxin and furans (dioxin-like compounds) is for the most toxic congener 2,3,7,8-tetrachloro-dibenzo-*p*-dioxin (2,3,7,8-TCDD). The other dioxin and furan congeners reported have varying degrees of toxicity. EPA has assigned toxicity equivalency factors (TEFs) to specific dioxin and furan congeners. 2,3,7,8-TCDD is assigned a TEF of 1; the other dioxin and furan congeners have TEFs less than 1. The toxicity equivalency (TEQ) is determined by multiplying the concentration of a dioxin and furan congener by its TEF. **Table 5-12** shows the concentrations of dioxin and furan compounds that were detected in at least one sample at concentrations exceeding the analytical reporting limits at locations NLIN2 and GEOCRK along with their TEFs and calculated TEQs. If one uses the conservative approach of adding those congeners that were not detected at concentrations equal to one-half the analytical reporting limits, total TEQs for locations NLIN2 and GEOCRK add up to 15 and 17 pg/L, respectively; total TEQs for location GEOCRK for the February 15 sampling event add up to 16 pg/L. Although the congener 2,3,7,8-TCDD has not been detected in this network, its contribution to the total TEQ is still a major factor when added at half the analytical reporting limit. These values are below the federal MCL of 30 pg/L for 2,3,7,8-TCDD and are well below the concentrations of similar dioxins and furans measured at locations NLIN (located slightly downstream from location NLIN2) and GEOCRK in 2002 (see *LLNL Site 300 Annual Storm Water Monitoring Report for Waste Discharge Requirements 97-03-DWQ Annual Report 2002–2003* [Sanchez 2003]). LLNL will continue to monitor storm water concentrations to determine if any trends are developing.

Environmental Impact of Storm Water

Storm water runoff from the Livermore site did not have any apparent environmental impacts in 2005. Tritium activities in storm water runoff

effluent were less than 1% of the drinking water MCL. Gross alpha and gross beta activities in effluent samples at the Livermore site were both far less than their respective MCLs. Site 300 storm water monitoring continues to show that most contaminants (including dioxins and furans, naturally occurring lead and uranium) are transported sorbed to suspended sediments in the water; however, these concentrations pose no threat to the environment.

Table 5-12. Total toxicity equivalents of dioxin and furan congeners in storm water runoff (pg/L) at Site 300, January 26 and February 15, 2005

Dioxin congener[a]	TEF[b]	January 26				February 15	
		NLIN2 concentration	TEQ[c]	GEOCRK concentration	TEQ[c]	GEOCRK concentration	TEQ[c]
2,3,7,8-TCDD	1.00	<9.7	4.85	<6.9	3.45	<2.1	1.05
Total-HxCDD	0.00	<10	0.0	<10	0.0	12	0.0
1,2,3,4,6,7,8-HpCDD	0.01	35	0.35	11	0.11	24	0.24
Total-HpCDD	0.00	88	0.00	35	0.00	48	0.00
Total-OCDD	0.0001	250	0.025	100	0.010	95	0.0095
2,3,7,8-TCDF	0.1	<5.2	0.26	<2.9	0.145	2.5	0.25
Total-TCDF	0.00	<2.1	0.00	<2.1	0.00	5.0	0.00
1,2,3,4,7,8-HxCDF	0.1	<10	0.5	<10	0.5	14	1.4
2,3,4,6,7,8-HxCDF	0.1	<10	0.5	<10	0.5	12	1.2
Total-HxCDF	0.0	<10	0.0	<10	0.0	67	0.0
1,2,3,4,6,7,8-HpCDF	0.01	<10	0.05	<10	0.05	64	0.64
Total-HpCDF	0.00	<10	0.0	<10	0.0	79	0.0
Total-OCDF	0.0001	43	0.0043	<21	0.001	63	0.0063

a TCDD = tetrachloro-dibenzo-*p*-dioxin
HxCDD = hexachloro-dibenzo-*p*-dioxin
HpCDD = heptachloro-dibenzo-*p*-dioxin
OCDD = octachloro-dibenzo-*p*-dioxin
TCDF = tetrachlorodibenzofuran
HxCDF = hexachlorodibenzofuran
HpCDF = heptachlorodibenzofuran
OCDF = octachlorodibenzofuran
b Toxicity Equivalency Factor compared to 2,3,7,8-TCDD
c Toxicity Equivalents compared to 2,3,7,8-TCDD

Groundwater

LLNL conducts surveillance monitoring of groundwater in the Livermore Valley and at Site 300 through networks of wells and springs that include private wells off site and DOE CERCLA wells on site.

The groundwaters monitored at the two LLNL facilities are not connected; they are separated by a major drainage divide and numerous faults. The Livermore site in the Livermore Valley drains to the San Francisco Bay via

Alameda Creek. Most of Site 300 drains to the San Joaquin River Basin via Corral Hollow Creek, with a small undeveloped portion in the north draining to the north and east onto grazing land.

To maintain a comprehensive, cost-effective monitoring program, LLNL determines the number and locations of surveillance wells, the analytes to be monitored, the frequency of sampling, and the analytical methods to be used. A wide range of analytes is monitored to assess the impact, if any, of current LLNL operations on local groundwater resources. Because surveillance monitoring is geared to detecting substances at very low concentrations in groundwater, contamination can be detected before it significantly impacts groundwater resources. Groundwater monitoring wells at the Livermore site, in the Livermore Valley, and at Site 300 are included in LLNL's surveillance monitoring plan.

Historically, the surveillance and compliance monitoring programs have detected higher than natural background concentrations of various metals, nitrate, perchlorate, and depleted uranium in groundwater at Site 300. Subsequent CERCLA studies have linked several of these contaminants, including depleted uranium, to past operations, while the sources of other contaminants, such as nitrate and perchlorate, are the objects of continuing study.

Beginning in January 2003, LLNL implemented a new CERCLA comprehensive compliance monitoring plan at Site 300 (Ferry et al. 2002) that adequately covers the DOE requirements for on-site groundwater surveillance; LLNL monitoring related to CERCLA activities is described in Chapter 8. Additional monitoring programs at Site 300 comply with numerous federal and state controls such as state-issued permits associated with closed landfills containing solid wastes and with continuing discharges of liquid waste to surface impoundments, sewage ponds, and percolation pits; the latter were discussed previously in this chapter. Compliance monitoring is specified in WDRs issued by the CVRWQCB and in landfill closure and post-closure monitoring plans. (See **Table 2-2** for a summary of LLNL permits.)

The WDRs and post-closure plans specify wells and effluents to be monitored, COCs and parameters to be measured, frequency of measurement, inspections to be conducted, and the frequency and form of required reports. These monitoring programs include quarterly and semiannual monitoring of groundwater, monitoring of various influent waste streams, and visual inspections. LLNL performs the maintenance necessary to ensure the physical integrity of closed facilities, such as those that have undergone CERCLA or RCRA closure, and their monitoring networks.

Typically, because they are both accurate and sensitive, analytical methods approved by EPA are used to measure dissolved constituents in water.

Appendix A lists the analytical methods and reporting limits that are used to detect organic and inorganic constituents in groundwater (including specific radioisotopes analyzed by alpha spectroscopy and other sensitive methods). The listed methods are not all used for samples from each groundwater monitoring location. Rather, for cost effectiveness, only those contaminants that have been detected historically or that might result from continuing LLNL operations are monitored at each groundwater sampling location. However, present-day administrative, engineering, and maintenance controls at both LLNL sites are specifically tailored to prevent releases of potential contaminants to the environment.

During 2005, representative samples of groundwater were obtained from monitoring wells in accordance with the LLNL Livermore Site and Site 300 Environmental Restoration Project Standard Operating Procedures (SOPs) (Goodrich and Depue 2003). These protocols cover sampling techniques and specific information concerning the chemicals that are routinely analyzed for in groundwater. Different sampling techniques were applied to different wells depending on whether they were fitted with submersible pumps, or had to be bailed. All of the chemical and radioactivity analyses of groundwater samples were performed by California-certified analytical laboratories. For comparison purposes only, some of the results are compared with drinking water limits (MCLs); however, the MCLs do not apply as regulatory limits to any of these groundwaters.

Livermore Site and Environs

Livermore Valley

LLNL has monitored tritium in water hydrologically downgradient of the Livermore site since 1988. Tritiated water (HTO) is potentially the most mobile groundwater contaminant from LLNL. Rain and storm water runoff in the Livermore Valley, which recharge local aquifers, contain small amounts of HTO from natural sources, past worldwide atmospheric nuclear weapons tests, and atmospheric emissions from LLNL. (See Chapters 4 and 7 for further discussion of air emissions, and other parts of this chapter for further discussion of rain and storm water runoff.)

Groundwater is recharged at the Livermore site, primarily from arroyos, by rainfall. Groundwater flow beneath the Livermore site is generally southwestward. An overview of groundwater flow is provided in Chapter 1 and is discussed in detail in the *CERCLA Remedial Investigation Report for the LLNL Livermore Site* (Thorpe et al. 1990) and in the LLNL Ground Water Project 2005 Annual Report (Karachewski et al. 2006).

Groundwater samples were obtained during 2005 from 23 of 25 water wells in the Livermore Valley (see **Figure 5-11**) and measured for tritium activity. Two wells were either dry or could not be sampled during 2005.

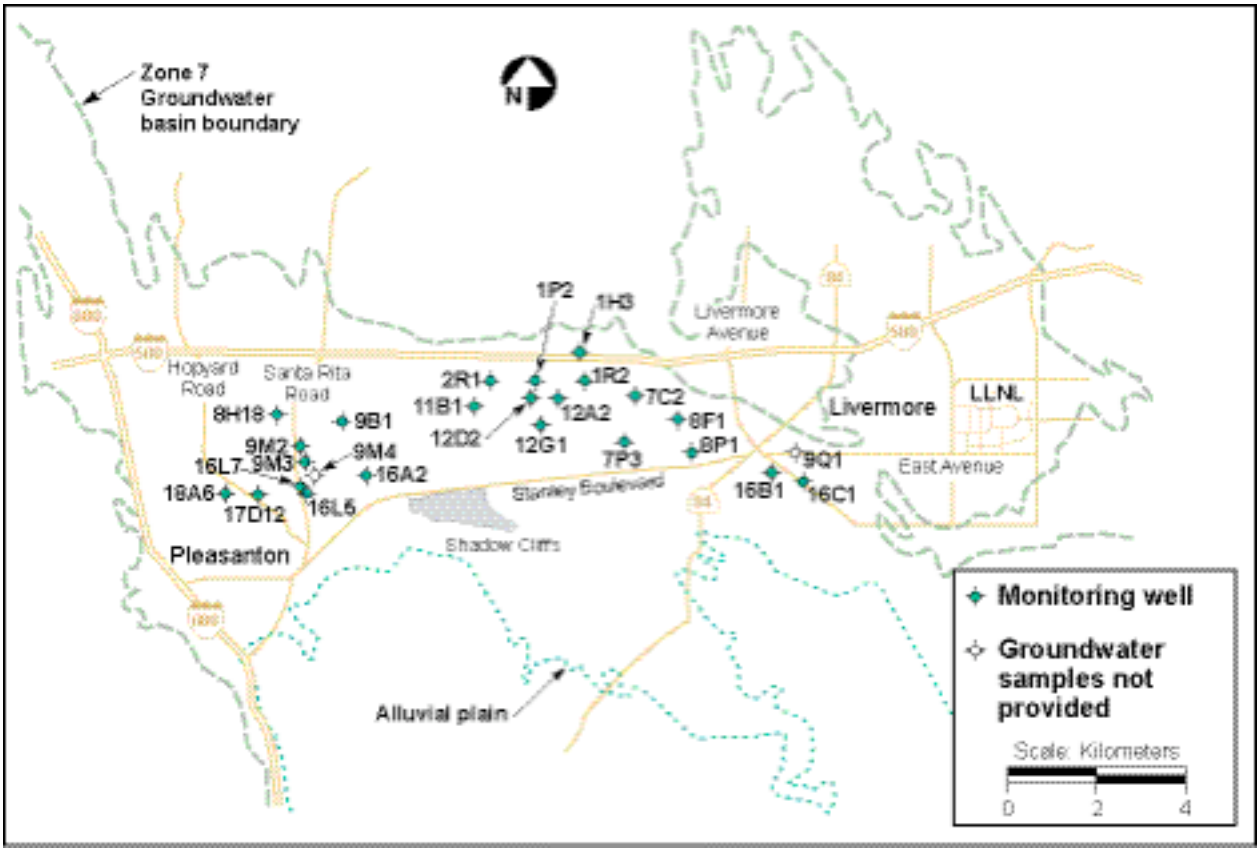


Figure 5-11. Locations of off-site tritium monitoring wells in the Livermore Valley, 2005

Tritium measurements of Livermore Valley groundwaters are contained in the file "Ch5 LV Groundwater" provided on the report CD. They continue to show very low and decreasing activities compared with the 740 Bq/L (20,000 pCi/L) MCL established for drinking water in California. The maximum tritium activity measured off site was in the groundwater at well 12A2, located about 9 km west of LLNL (see **Figure 5-11**). The measured activity there was 4.3 Bq/L (116 pCi/L) in 2005, less than 1% of the MCL.

Livermore Site Perimeter

LLNL designed a surveillance monitoring program to complement the Livermore Site GWP (discussed in Chapter 8). The intent of the surveillance monitoring network is to monitor for potential groundwater contamination from continuing LLNL operations. The perimeter portion of this surveillance groundwater monitoring network makes use of three upgradient

(background) monitoring wells (wells W-008, W-221, and W-017) near the eastern boundary of the site and seven (downgradient) monitoring wells located near the western boundary (wells 14B1, W-121, W-151, W-1012, W-571, W-556, and W-373) (see **Figure 5-12**). These seven wells, located in the regions of groundwater Treatment Facilities (TF) A, B, and C (see **Figure 8-1**) are located at or beyond the hydrologically downgradient boundary of the Livermore site. The western perimeter wells are screened (depth range from which groundwater is drawn) in the uppermost aquifers near the areas where groundwater is being remediated. As discussed in Chapter 8, the alluvial sediments have been divided into nine hydrostratigraphic units (HSUs) dipping gently westward, which are shown in **Figure 8-1**. Screened intervals for these monitoring wells range from the shallow HSU 1B, in which some of the western monitoring wells are screened, to the deeper HSU 5, in which background well W-017 and some wells around Buildings 514 and 612 are screened.

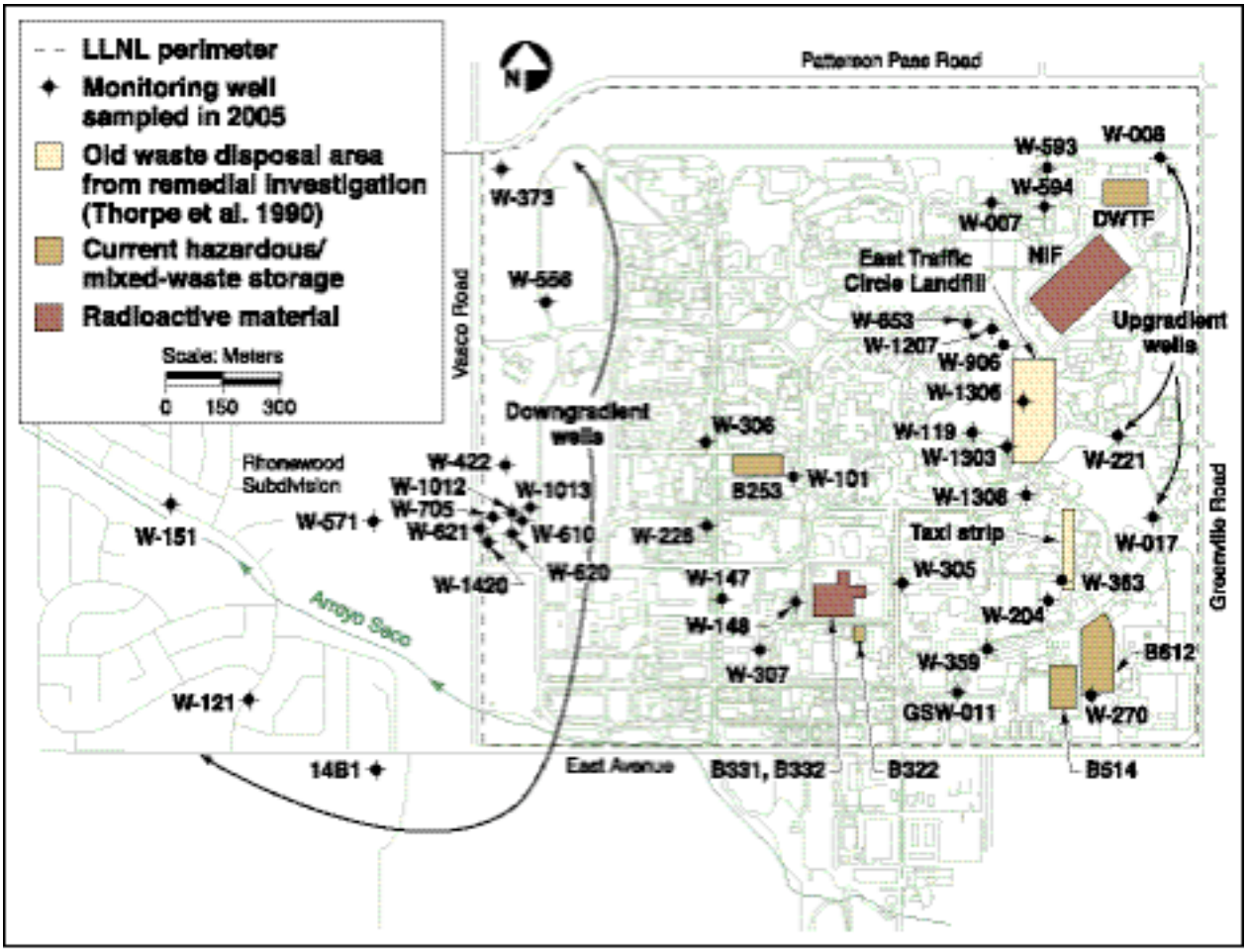


Figure 5-12. Locations of routine surveillance groundwater monitoring wells at the Livermore site, 2005

Two of the background wells, W-008 and W-221, are screened partially in HSU 3A; well W-017 is considered a background well for the deeper HSU 5. These background wells were sampled and analyzed in 2005 for pesticide and herbicide compounds that are used on site and off site, for nitrate, for hexavalent chromium (chromium(VI)), and for certain radioactive constituents including plutonium.

To detect contaminants as soon as possible, the seven western downgradient wells (except for well 14B1) are screened in shallower HSUs 1B and 2, the uppermost water-bearing HSUs at the western perimeter. (Because it was originally a production well, well 14B1 is screened over a depth range that includes HSUs 2, 3A, and 3B.) These wells were sampled and analyzed at least once during this reporting period for pesticides, herbicides, radioactive constituents, nitrate, and chromium(VI).

Analytical results for the Livermore site background wells and perimeter wells are contained in the file "Ch5 LV Groundwater" provided on the report CD. One sample from the background well W-017 was reported to contain the herbicide merphos (1.8 µg/L); however, this result is suspect due to analytical (QC) complications reported by the laboratory. An independent retest of this well in January 2006 failed to confirm this detection. No pesticide or herbicide organic compounds were detected above analytical reporting limits in groundwater samples from the other background or perimeter wells during 2005. The inorganic compounds detected include dissolved trace metals and minerals, which occur naturally in the groundwater. Although there have been variations in these concentrations since regular surveillance monitoring began in 1996, the concentrations detected in the 2005 groundwater samples from the upgradient wells represent current background values. Plutonium-238 and plutonium-239+240 were reported above minimum detectable activities in one perimeter well sample, collected from well W-1012 in March 2005. Failure to filter this sample prior to analysis, however, invalidated these results; nevertheless, two retests were initiated. Analytical results from samples collected at well W-1012 in both May 2005 and December 2005 failed to confirm the initial detection.

Since 1996, and continuing through 2004, concentrations of nitrate detected in groundwater samples from downgradient well W-1012 had been greater than the MCL of 45 mg/L. The nitrate concentrations detected in samples from this well during 2005 were reported at 43 and 41 mg/L; these values are less than the values of 61 and 45 mg/L observed in 2004, and are now below the MCL. Because of the hydrologic influence of TFB that pumps and treats groundwater from HSUs 1B and 2, groundwater with high nitrate concentrations is restrained from moving off site to the west. The highest concentrations measured in the downgradient off-site wells (screened in these HSUs) remained below the MCL: 41 mg/L in monitoring well W-151 and 37 mg/L in monitoring well W-571. During 2005, concentrations of nitrate in

on-site shallow background wells W-008 and W-221 ranged from 24 mg/L to 29 mg/L. Detected concentrations of nitrate in western perimeter wells, with the exception of well W-1012, ranged from 13 mg/L (in well W-373) to 42 mg/L (in well W-556).

Nitrate concentrations were also analyzed in groundwater samples collected from seven additional monitoring wells located nearby well W-1012 (**Figure 5-12**), similarly screened in HSUs 1B and 2. Again, no groundwater sample had a nitrate concentration greater than the MCL. Fluctuations in nitrate concentrations have occurred since regular surveillance monitoring began in 1996, but nitrate concentrations have not increased overall in groundwater from the western perimeter monitoring wells since 1996. The nitrate may originate as an agricultural residue (Thorpe et al. 1990).

Livermore Site

Groundwater sampling locations within the Livermore site include areas where releases to the ground may have occurred in the recent past, where previously detected COCs have low concentrations that do not require CERCLA remedial action, and where baseline information needs to be gathered for the area near a new facility or operation. Wells selected for monitoring are screened in the uppermost aquifers, and are situated downgradient from and as near as possible to the potential release locations. Well locations are shown in **Figure 5-12**. All analytical results are included in the file "Ch5 LV Groundwater" provided on the report CD.

The Taxi Strip and the East Traffic Circle Landfill areas within the Livermore site are two historic potential sources of groundwater contamination. Samples from monitoring wells screened in HSUs 2 (W-204) and 3A (W-363) downgradient from the Taxi Strip Area were analyzed in 2005 for copper, lead, zinc, americium-241, plutonium-238, plutonium-239, radium-226, radium-228, and tritium. Samples from monitoring wells screened at least partially in HSU 2 (W-119, W-906, W-1303, W-1306, and W-1308) within and downgradient from the East Traffic Circle Landfill were analyzed for the same elements as in the Taxi Strip Area. No concentrations of plutonium or americium radioisotopes were detected above the radiological laboratory's minimum detectable activities. Concentrations of tritium and radium isotopes remain well below drinking water MCLs. Of the trace metals (copper, lead, and zinc), only zinc was detected in any of these monitoring wells during 2005. Zinc concentrations were reported as 26 µg/L in well W-119, 11 µg/L in well W-204, and <10 µg/L in four of these wells (W-363, W-1303, W-1306, and W-1308). The maximum zinc concentration reported in 2005 (500 µg/L in well W-906) is still an order of magnitude below the secondary MCL for zinc in drinking water (5000 µg/L).

Although the National Ignition Facility (NIF) has not yet begun full operations, LLNL obtains a baseline (pH, conductivity, and tritium concentration) of groundwater quality prior to start of operations. During 2005, tritium analyses were conducted on groundwater samples collected from wells W-653 and W-1207 (screened in HSUs 3A and 2, respectively) downgradient of NIF. Another new facility where groundwater baseline information is being acquired is the Decontamination and Waste Treatment Facility (DWTF) in the northeastern portion of LLNL. Samples were obtained downgradient from this facility from wells W-007, W-593, and W-594 (screened in HSUs 2/3A, 3A, and 2, respectively) during 2005 and were analyzed for tritium.

Monitoring results from the wells near NIF and DWTF show no detectable concentrations of tritium present, above the limit of sensitivity of the analytical method, in the groundwater samples collected during 2005. Monitoring will continue near these facilities to determine baseline conditions.

Area 514 and the hazardous waste/mixed waste storage facilities around Building 612 are also a potential source of contamination. They are monitored by wells W-270 and W-359 (both screened in HSU 5), and well GSW-011 (screened in HSU 3A). Groundwater from these wells was sampled and analyzed for general minerals, americium-241, plutonium-238, plutonium-239, radium-226, and tritium in 2005. No significant contamination was detected in the groundwater samples collected from wells W-270, W-359, or GSW-011 downgradient from those areas in 2005.

Groundwater samples were obtained from monitoring well W-307 (screened in HSU 1B). This location, downgradient from a fume hood vent on the roof of Building 322 (a metal plating shop), is an area where releases of metals to the ground have occurred. Soil samples previously obtained from the area showed elevated concentrations (in comparison with Livermore site's background levels) of total chromium, copper, lead, nickel, zinc, and occasionally other metals. LLNL removed contaminated soils near Building 322 in 1999 and replaced them with clean fill. The area was then paved over, making it less likely that metals will migrate from the site. In 2005, the monitoring results for well W-307 show only slight variations from the concentrations reported in recent years.

Groundwater samples were obtained downgradient from a location where sediments containing metals (including cadmium, chromium, copper, lead, mercury, and zinc) had accumulated in a storm water catch basin near Building 253. The accumulated sediment in the catch basin is a potential source of several metals (Jackson 1997). In 2005, the samples obtained from monitoring wells W-226 and W-306 (screened in HSUs 1B and 2, respectively) contained dissolved chromium at elevated concentrations, but concentrations

were essentially unchanged from last year. Concentrations of chromium(VI) were measured as 26 µg/L at well W-226 and 35 µg/L at well W-306. No concentration of either dissolved chromium or chromium(VI) was greater than the MCL of 50 µg/L for total chromium in drinking water.

Additional surveillance groundwater sampling locations, established in 1999, surround the area of the Plutonium Facility (Building 332) and the Tritium Facility (Building 331) (see **Figure 5-12**). Possible contaminants include plutonium and tritium from these respective facilities. Plutonium is much more likely to bind to the soils than migrate into the groundwater. Tritium, as HTO, could migrate into groundwater if spilled in sufficient quantities. Upgradient of these facilities, well W-305 is screened in HSU 2; down-gradient wells W-101, W-147, and W-148 are screened in HSU 1B. Groundwater samples collected from these wells during 2005 showed no detectable concentration, above the limit of sensitivity for the analytical method, of either plutonium-238 or plutonium-239+240.

In August 2000, relatively elevated tritium activity was measured in the groundwater sampled at well W-148 (115 ± 5.0 Bq/L [3100 ± 135 pCi/L]). It was concluded that the activity was most likely related to local infiltration of storm water containing elevated tritium activity. Tritium activities in groundwater of this area have generally remained at this level since that time. LLNL continues to collect groundwater samples from these wells periodically for surveillance purposes, primarily to demonstrate that tritium and plutonium contents remain below environmental levels of concern.

Site 300 and Environs

For surveillance and compliance groundwater monitoring at Site 300, LLNL uses DOE CERCLA wells and springs on site and private wells and springs off site. Representative groundwater samples are obtained at least once per year at every monitoring location; they are routinely measured for various elements (primarily metals), a wide range of organic compounds, general radioactivity (gross alpha and gross beta), uranium activity, and tritium activity. Groundwater from the shallowest water-bearing zone is the target of most of the monitoring because it would be the first to show contamination from LLNL surface or sub-surface operations at Site 300.

Twelve groundwater monitoring locations are off site (**Figure 5-13**). Two are springs, identified as MUL2 and VIE1, which are located near the northern boundary of Site 300. Off-site surveillance well VIE2 is located 6 km west of Site 300 in the upper reaches of the Livermore Valley watershed. Eight off-site surveillance locations are wells located near the southern boundary of Site 300 in or adjacent to the Corral Hollow Creek floodplain.

On-site wells are used to monitor closed landfills, a former open-air explosives burn pit, two connected surface water impoundments, and two connected sewer ponds (**Figure 5-13**). The closed landfills—identified as Pit 1, Pit 2, Pit 7 Complex, Pit 8, and Pit 9—are located in the northern portion of Site 300 in the Elk Ravine drainage area, while Pit 6, the former burn pit (Building 829), the two surface impoundments, and the sewage ponds are located in the southern portion of Site 300 in the Corral Hollow Creek drainage area. Two on-site water supply wells, identified as wells 18 and 20, are also used for surveillance monitoring purposes. Well 20 provides potable water to the site. Well 18 is maintained as a standby potable supply well.

Brief descriptions of the Site 300 groundwater monitoring networks that are reported in this chapter are given below. Networks of wells within the Elk Ravine drainage area are described first, followed by the well networks in the Corral Hollow Creek drainage area. Subsets of CERCLA wells, installed mainly for site characterization, have been selected for compliance and surveillance monitoring use based on their locations and LLNL's general understanding of local geologic and hydrogeologic conditions at Site 300. (Chapters 1 and 8 include summaries of Site 300 hydrology and stratigraphy, respectively. All analytical data from 2005 are included in the file "Ch5 S300 Groundwater" provided on the report CD.)

Elk Ravine Drainage Area

The Elk Ravine drainage area, a branch of the Corral Hollow Creek drainage system, includes most of northern Site 300 (see **Figure 5-13**). Storm water runoff in the Elk Ravine drainage area collects in arroyos and quickly infiltrates into the ground. Groundwater from wells in the Elk Ravine drainage area is monitored for COCs because of the system of surface and underground flows that connects the entire Elk Ravine drainage area. The area contains eight closed landfills known as Pits 1 through 5 and 7 through 9 and firing tables where explosives tests are conducted. None of the closed landfills has a liner, which is consistent with disposal practices in the past when the landfills were constructed. The following descriptions of monitoring networks within Elk Ravine begin with the headwaters area and proceed downstream. (See Chapter 8 for a review of groundwater contamination in this drainage area as determined from numerous CERCLA remedial investigations.)

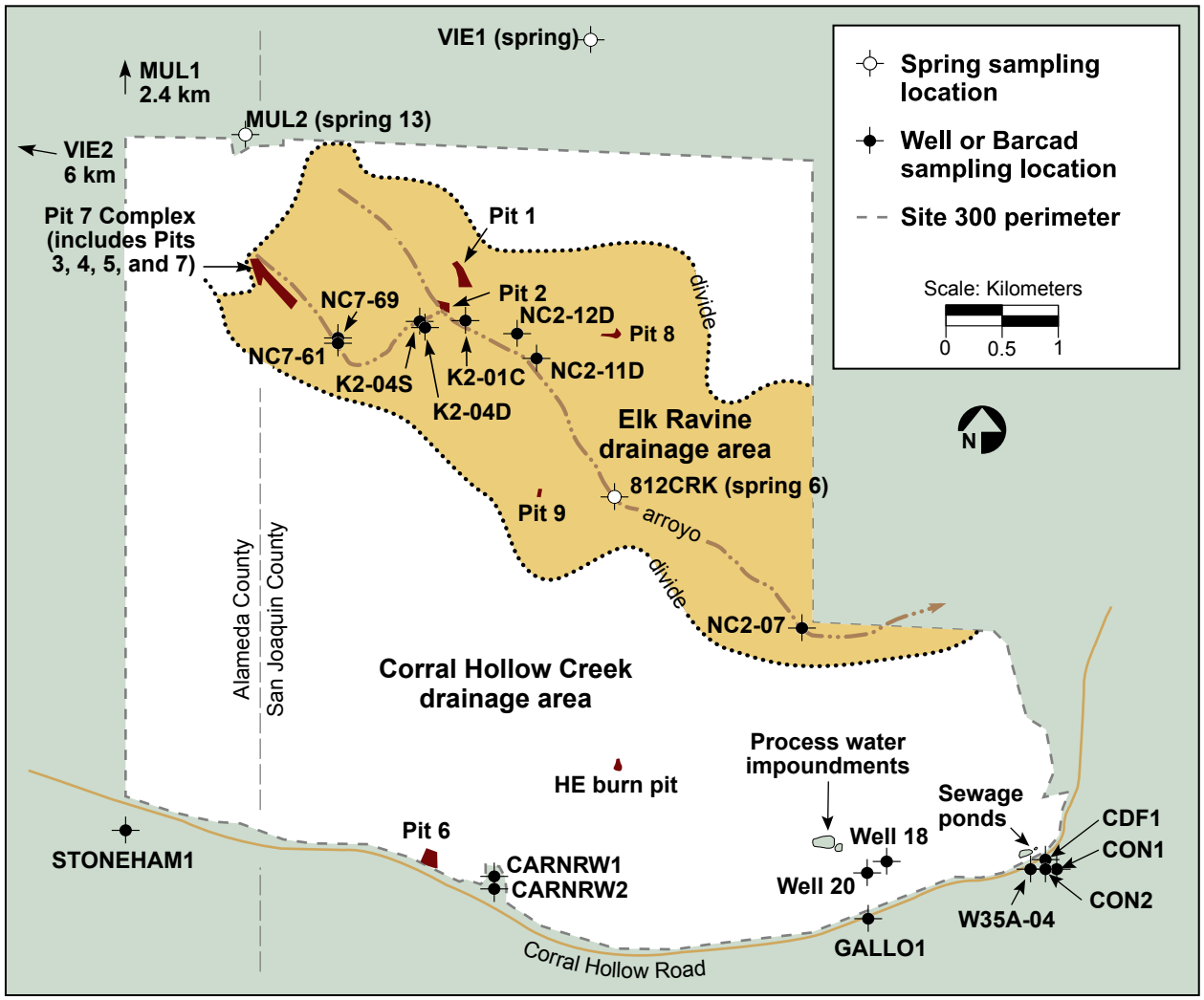


Figure 5-13. Locations of surveillance groundwater wells and springs at Site 300, 2005

Pit 7 Complex

Monitoring requirements for the Pit 7 landfill, which was closed under the Resource Conservation and Recovery Act (RCRA) in 1993, are specified in WDR 93-100 administered by the CVRWQCB (1993, 1998a) and in *LLNL Site 300 RCRA Closure and Post-Closure Plans—Landfill Pits 1 and 7* (Rogers/Pacific Corporation 1990). The main objective of this monitoring is the early detection of any new release of COCs from Pit 7 to groundwater.

The Pit 7 Complex area is located at an elevation of about 400 m above sea level in the most elevated portion of the Elk Ravine drainage area. The complex consists of four adjacent landfills identified as Pits 3, 4, 5, and 7 (see **Figure 5-14**). From 1963 to 1988, the landfills received waste gravels and debris from hydrodynamic tests of explosive devices conducted on firing tables at Site 300. The gravels contained concrete, cable, plastic, wood,

tritium, uranium, beryllium, lead, and other metals in trace amounts. In 1988, 9440 m^3 of gravel were removed from six firing tables at Site 300 and placed in Pit 7 (Lamarre and Taffet 1989). These were the last solid wastes to be placed in any landfill at Site 300.

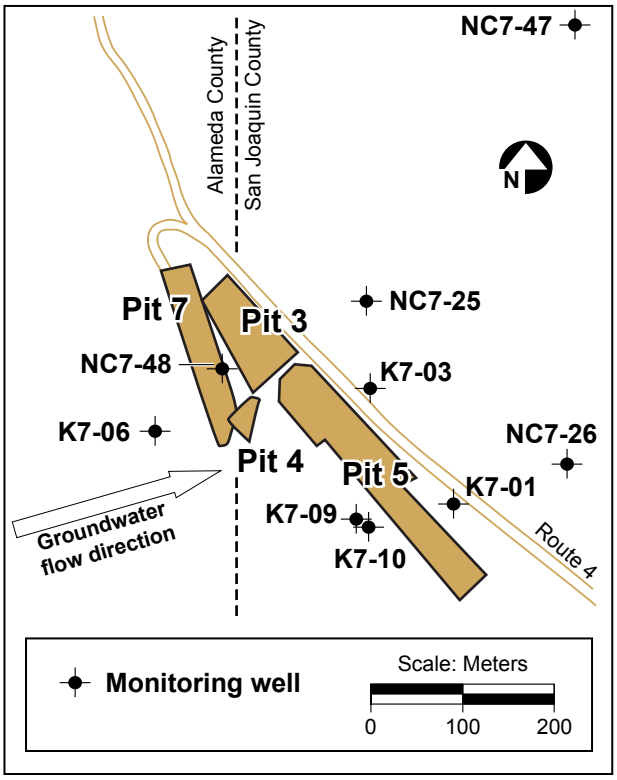


Figure 5-14. Locations of Pit 7 compliance groundwater monitoring wells, 2005

As planned for compliance purposes, LLNL obtained groundwater samples quarterly during 2005 from the Pit 7 monitoring well network. Samples were analyzed for inorganic COCs (mostly metallic elements), general radioactivity (gross alpha and beta), activity of certain radioisotopes (tritium, radium, uranium, and thorium), explosive compounds (HMX and RDX), and volatile organic compounds (VOCs). Field measurements of groundwater depth, temperature, pH, and specific conductance were obtained at each well at the time of sample collection.

No new release of COCs to groundwater from Pit 7 is evident in the chemical data obtained during 2005. The COCs detected in groundwater include several metals, depleted uranium, tritium, and several VOCs. These are associated with releases that occurred prior to 2005. The primary sources of COCs detected by the network of Pit 7 monitoring wells are the closed landfills known as Pits 3 and 5, which are adjacent to Pit 7 (**Figure 5-14**). Natural sources in the rocks and sediments surrounding Pit 7 also have

contributed arsenic, barium, uranium, and, possibly nitrate to the groundwater. In the past, especially during the El Niño winters of 1982/1983 and 1997/1998, excessive seasonal rainfall caused groundwater levels to rise into Pit 3 and Pit 5 from beneath, leading to the release of COCs, mainly tritium in the form of HTO. Because of reduced rainfall since 1998, groundwater elevations have fallen generally at Site 300, thus reducing the potential for releases to occur by this mechanism. CERCLA modeling studies indicate that tritium and other COCs released in the past will not reach off-site aquifers at concentrations above MCLs. See Chapter 8 for a review of CERCLA activities regarding groundwater contamination in the upper reaches of the Elk Ravine drainage area. For a detailed account of Pit 7 compliance monitoring during 2005, including tables and graphs of groundwater COC analytical data, see *LLNL Experimental Test Site 300 Compliance Monitoring Program for RCRA-Closed Landfill Pits 1 and 7, Annual Report for 2005* (Campbell and MacQueen 2006).

Elk Ravine

Groundwater samples were obtained on various dates in 2005 from the widespread Elk Ravine surveillance monitoring network (see **Figure 5-13**). Samples were analyzed for inorganic constituents (mostly metallic elements), VOCs, general radioactivity (gross alpha and beta), tritium and uranium activity, and explosive compounds (HMX and RDX).

No new release of COCs from LLNL operations in Elk Ravine to groundwater is indicated by the chemical and radioactivity data obtained during 2005. The major source of contaminated groundwater beneath Elk Ravine is from historical operations in the Building 850 firing table area (Webster-Scholten 1994; Taffet et al. 1996). Constituents that are measured as part of the Elk Ravine drainage area surveillance monitoring network are listed in Appendix A.

Concentrations of arsenic range up to 43 µg/L (well NC2-07) in Elk Ravine monitoring wells. Earlier CERCLA characterization studies determined that the arsenic is from natural sources, particularly from the dissolution of the mineral arsenopyrite, which is a component of the underlying volcanogenic sediments and sedimentary rocks (Raber and Carpenter 1983). It should be noted that there are no wells in this area that are used for potable domestic, livestock, or industrial water supply. However, a perennial spring in Elk Ravine (location 812CRK on **Figure 5-13**), which is used by the indigenous wildlife there, contains concentrations of naturally occurring arsenic (28 µg/L arsenic in 2005).

An elevated tritium activity was detected in one of five shallow groundwater surveillance samples collected from wells in Elk Ravine during 2005. Tritium, as HTO, has been released in the past in the vicinity of Building 850. The largest HTO plume, which extends eastward more than a kilometer from a

source beneath the Building 850 firing table area to the vicinity of Pits 1 and 2, is confined to shallow depths in the Neroly lower blue sandstone unit and overlying alluvium.

The majority of the Elk Ravine surveillance network tritium measurements made during 2005 support earlier CERCLA studies that show that the tritium in the plume is diminishing over time because of natural decay and dispersion (Ziagos and Reber-Cox 1998). For example, tritium activity in groundwater at well NC7-61 has decreased from 6500 Bq/L (1.8×10^5 pCi/L) in 1996 to 1150 Bq/L (3.1×10^4 pCi/L) in 2005. CERCLA modeling studies indicate that the tritium will decay to background levels before it can reach a site boundary. Note that the tritium plume has not yet reached the surveillance monitoring perennial spring location 812CRK, which is approximately one mile upstream from where the Site 300 boundary crosses Elk Ravine.

Groundwater surveillance measurements of gross alpha, gross beta, and uranium radioactivity in Elk Ravine are all low and are indistinguishable from background levels. (Note that gross beta measurements do not detect the low-energy beta emission from tritium decay.) Additional detections of nonradioactive elements including arsenic, barium, chromium, selenium, vanadium, and zinc are all within the natural ranges of concentrations typical of groundwater elsewhere in the Altamont Hills.

Pit 1

Monitoring requirements for the Pit 1 landfill, which was closed under RCRA in 1993, are also specified in WDR 93-100 administered by the CVRWQCB (1993 and 1998) and in Rogers/Pacific Corporation (1990). The main objective of this monitoring is the early detection of any release of COCs from Pit 1 to groundwater.

Pit 1 lies in the Elk Ravine drainage area about 330 m above sea level. The Pit 1 landfill and the positions of the eight groundwater wells used to monitor it are shown in **Figure 5-15**. The eight wells are K1-01C, K1-02B, K1-03, K1-04, K1-05, K1-07, K1-08, and K1-09.

As planned for compliance purposes, LLNL obtained groundwater samples quarterly during 2005 from the Pit 1 monitoring well network. Samples were analyzed for inorganic COCs (mostly metallic elements), general radioactivity (gross alpha and beta), activity of certain radioisotopes (tritium, radium, uranium, and thorium), explosive compounds (HMX and RDX), and VOCs (EPA method 601). Every other quarter, analyses were conducted for an additional seven elements. Additional annual analyses were conducted on fourth-quarter samples for extractable organics (EPA method 625), pesticides and PCBs (EPA method 608), and herbicides (EPA method 615). Field

measurements of groundwater depth, temperature, pH, and specific conductance were obtained at each well at the time of quarterly sample collection.

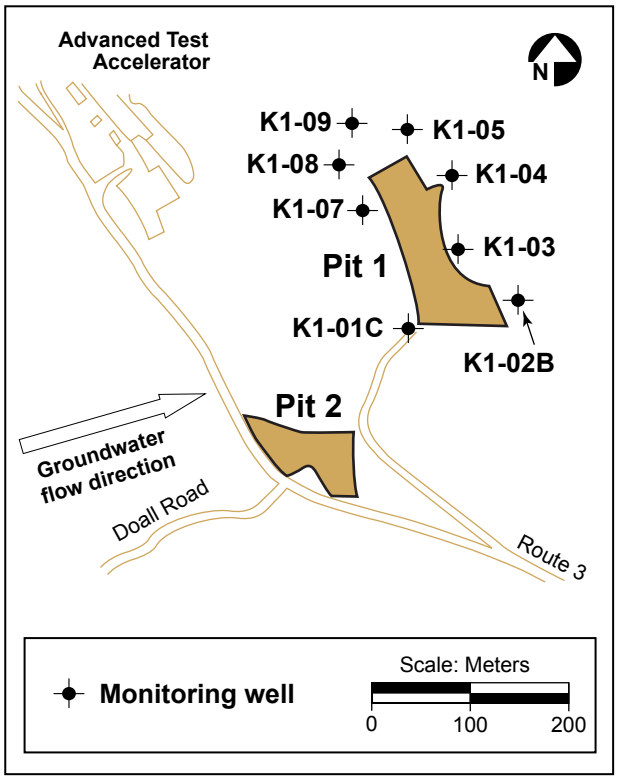


Figure 5-15. Locations of Pit 1 compliance groundwater monitoring wells, 2005

No release of COCs to groundwater from Pit 1 is evident in the monitoring data collected during 2005. A detailed account of Pit 1 compliance monitoring during 2005, including tables and graphs of groundwater COC analytical data, is in *LLNL Experimental Test Site 300 Compliance Monitoring Program for RCRA-Closed Landfill Pits 1 and 7, Annual Report for 2005* (Campbell and MacQueen 2006).

During 2005, average tritium activities above analytical background levels (about 4 Bq/L [100 pCi/L]) were measued in the groundwater at Pit 1 monitoring wells K1-01C (24 Bq/L [641 pCi/L]), K1-02B (145 Bq/L [3908 pCi/L]), K1-03 (31 Bq/L [832 pCi/L]), K1-04 (6 Bq/L [165 pCi/L]), K1-08 (6 Bq/L [165 pCi/L]), and K1-09 (6 Bq/L [165 pCi/L]). The tritium activity in the groundwater sampled at these wells represents a distal lobe of the Building 850 tritium plume. Measurements of radium, thorium, and uranium made during 2005 in groundwater samples from Pit 1 compliance monitoring wells showed low activities indistinguishable from background levels.

The VOC 1,1,2-trichloro-1,2,2-trifluoroethane (Freon 113) decreased from a maximum concentration of 140 µg/L measured in 1999 to 42 µg/L in 2005 in groundwater samples at Pit 1 monitoring well K1-09. Freon-113 concentrations were also found at other groundwater monitoring wells K1-05 (15 µg/L) and K1-08 (26 µg/L). The drinking water MCL for this VOC is 1200 µg/L. Previous CERCLA investigations have linked the Freon 113 detected in Pit 1 monitoring wells to past spills of Freon in the Advanced Test Accelerator area, about 200 m northwest of the affected wells (Webster-Scholten 1994; Taffet et al. 1996).

Corral Hollow Creek Drainage Area

Pit 6

Compliance monitoring requirements for the closed Pit 6 landfill in the Corral Hollow Creek drainage area are specified in the *Post-Closure Plan for the Pit 6 Landfill Operable Unit Lawrence Livermore National Laboratory Site 300* (Ferry et al. 1998) and in the *Compliance Monitoring Plan/ Contingency Plan for Interim Remedies at Lawrence Livermore National Laboratory Site 300* (Ferry et al. 2002). The closed Pit 6 landfill covers an area of about 1 hectare (2.5 acres), at an elevation of approximately 215 m above sea level. From 1964 to 1973, approximately 1500 m^3 of solid wastes were buried there in nine separate trenches. The trenches were not lined, consistent with historical disposal practices. Three larger trenches contain 1300 m^3 of solid waste that includes empty drums, glove boxes, lumber, ducting, and capacitors. Six smaller trenches contain 230 m^3 of biomedical waste, including animal carcasses and animal waste. During 1997, a multilayered cap was constructed over all the trenches, and a storm water drainage control system was installed around the cap. The cap and the drainage control system are engineered to keep rainwater from contacting the buried waste (Ferry et al. 1998).

The Pit 6 disposal trenches were constructed in Quaternary terrace deposits (Qt) north of the Corral Hollow Creek flood plain. Surface runoff from the pit area flows southward to Corral Hollow Creek. The Carnegie-Corral Hollow Fault zone extends beneath the southern third of Pit 6. The northern limit of the fault zone is shown in **Figure 5-16**. Beneath the northern two-thirds of Pit 6, groundwater flows south-southeast, following the inclination of the underlying sedimentary rocks. Groundwater seepage velocities are less than 10 m/y. Depths to the water table range from 10 to 20 m. Beneath the southern third of Pit 6, a trough containing terrace gravel within the fault zone provides a channel for groundwater to flow southeast, parallel to the Site 300 boundary fence (Webster-Scholten 1994).

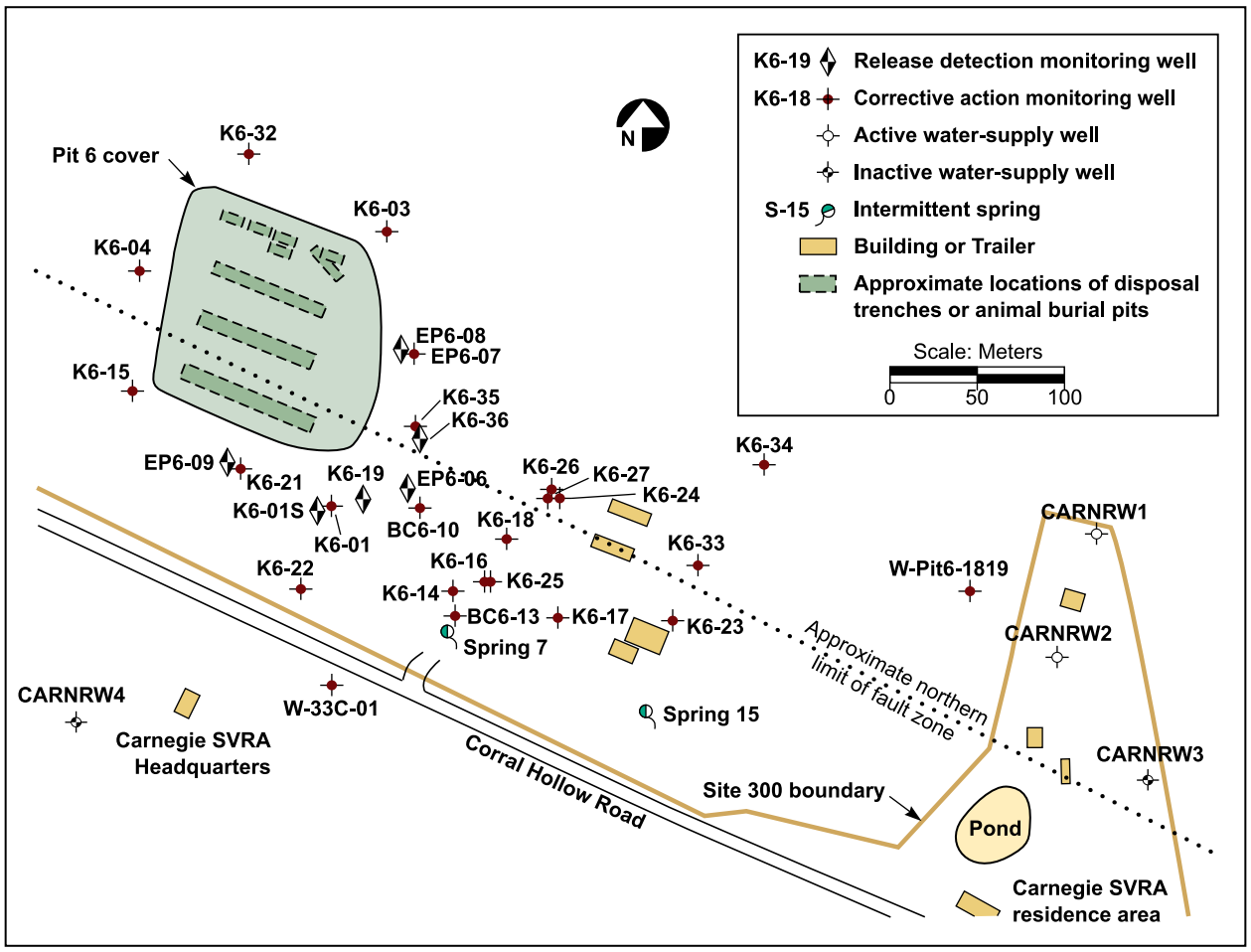


Figure 5-16. Locations of Pit 6 compliance groundwater monitoring wells and springs, 2005

Two Pit 6 groundwater monitoring programs, which operate under CERCLA, ensure compliance with all regulations. They are (1) the Detection Monitoring Program (DMP), designed to detect any new release of COCs to groundwater from wastes buried in the Pit 6 landfill, and (2) the Corrective Action Monitoring Program (CAMP), which monitors the movement and fate of historical releases. **Figure 5-16** shows the locations of Pit 6 and the wells used to monitor the groundwater there. To comply with monitoring requirements, LLNL obtained groundwater samples monthly, quarterly, semiannually, and annually during 2005 from specified Pit 6 monitoring wells. DMP samples were obtained quarterly and were analyzed for beryllium and mercury, general radioactivity (gross alpha and beta), tritium and uranium activity, specified VOCs, nitrate and perchlorate. CAMP samples were measured for VOCs, tritium activity, nitrate and perchlorate. Field measurements of groundwater depth, temperature, pH, and specific conductance were obtained at each well at the time of sample collection.

No new release of COCs from Pit 6 is indicated by the chemical analyses of groundwater samples obtained from Pit 6 monitoring wells during 2005. COCs that were released prior to constructing an impermeable cap over the closed landfill in 1997 continued to be detected in the groundwater at low concentrations during 2005. These COCs include tritium, perchlorate, trichloroethylene (TCE), perchloroethylene (PCE), and cis-1,2-dichloroethene (cis-1,2-DCE). All contaminant plumes associated with Pit 6 are confined to shallow depths. None has been detected beyond the Site 300 boundary. For a detailed account of Pit 6 compliance monitoring during 2005, including tables of groundwater analytical data and map figures showing the distribution of COC plumes, see *LLNL Experimental Test Site 300 Compliance Monitoring Program for the CERCLA-Closed Pit 6 Landfill, Annual Report for 2005* (Campbell and Taffet 2006).

Building 829 Closed HE Burn Facility

Compliance monitoring requirements for the closed burn pits in the Corral Hollow Creek drainage area are specified in the *Final Closure Plan for the High-Explosives Open Burn Treatment Facility at Lawrence Livermore National Laboratory Experimental Test Site 300* (Mathews and Taffet 1997), and in the *Revisions to the Post-Closure Permit Application for the Building 829 HE Open Burn Facility – Volume 1* (LLNL 2001b) as modified by the *Hazardous Waste Facility Post-Closure Permit for the Building 829 HE Open Burn Facility* (DTSC 2003).

The former Burn Facility, part of the Building 829 Complex, is located on a ridge within the southeast portion of Site 300 at an elevation of about 320 m above sea level. The facility included three shallow, unlined pits constructed in unconsolidated sediments that cap the ridge (Tps formation). The facility was used to thermally treat explosives process waste generated by operations at Site 300 and similar waste from explosives research operations at the Livermore site. The facility was covered with an impervious cap in 1998 following RCRA guidance.

Surface water drains southward from the facility toward Corral Hollow Creek. The nearest site boundary lies about 1.6 km to the south at Corral Hollow Road. Stratified rocks of the Neroly (Tn) formation underlie the facility and dip southeasterly. Two water-bearing zones exist at different depths beneath the facility. The shallower zone, at a depth of about 30 m, is perched within the Neroly upper siltstone/claystone aquitard ($Tnsc_2$). The deeper zone, at a depth of about 120 m, represents a regional aquifer within the Neroly upper sandstone member ($Tnbs_2$). (See **Figure 8-5** for Site 300 stratigraphy.)

Based on groundwater samples recovered from boreholes, previous CERCLA remedial investigations determined that the perched groundwater near the Burn Facility was contaminated with VOCs, primarily TCE, but that the

deeper regional aquifer was free of any contamination stemming from operation of the facility (Webster-Scholten 1994). Subsequent assays of soil samples obtained from shallow boreholes prior to closure revealed that low concentrations of explosives compounds, VOCs, and metals exist beneath the burn pits (Mathews and Taffet 1997). Conservative transport modeling indicates that the shallow contamination will not adversely impact the regional aquifer primarily because its downward movement is blocked by more than 100 m of unsaturated Neroly Formation sediments that include interbeds of claystone and siltstone.

Beginning in 1999, LLNL implemented the intensive groundwater monitoring program for this area described in the post-closure plan (Mathews and Taffet 1997) to track the fate of contaminants in the soil and the perched water-bearing zone, and to monitor the deep regional aquifer for the appearance of any potential contaminants from the Burn Facility. This monitoring program remained in effect through the first quarter of 2003, at which time LLNL began implementation of the provisions specified in the *Hazardous Waste Facility Post-Closure Permit for the B829 Facility* (DTSC 2003). Following the guidance outlined in the DTSC Technical Completeness assessment (DTSC 2002), LLNL installed one additional groundwater monitoring well at the point of compliance within three meters of the edge of the capped High Explosive Open Burn Treatment Facility. This well (W-829-1938) was screened in the regional aquifer, the uppermost aquifer beneath the Building 829 facility. Since the first quarter of 2004, and continuing through 2005, well W-829-1938 has been used for quarterly collection of groundwater samples from the regional aquifer, as part of the permit-specified monitoring network (**Figure 5-17**). Also shown in **Figure 5-17** are two previously existing wells (W-829-15 and W-829-22), which were sampled in both the first and second quarters of 2005, prior to the DTSC-approved change (from quarterly to annual) in sampling frequency for wells W-829-15 and W-829-22 (DTSC 2005).

As planned for compliance purposes, LLNL obtained groundwater samples during 2005 from the Building 829 monitoring well network. Groundwater samples from the wells screened in the deep regional aquifer were analyzed for inorganic COCs (mostly metals), general minerals, turbidity, explosive compounds (HMX, RDX, and TNT), VOCs (EPA method 624), extractable organics (EPA method 625), pesticides (EPA method 608), herbicides (EPA method 615), general radioactivity (gross alpha and beta), radium activity, total organic carbon (TOC), total organic halides (TOX), and coliform bacteria.

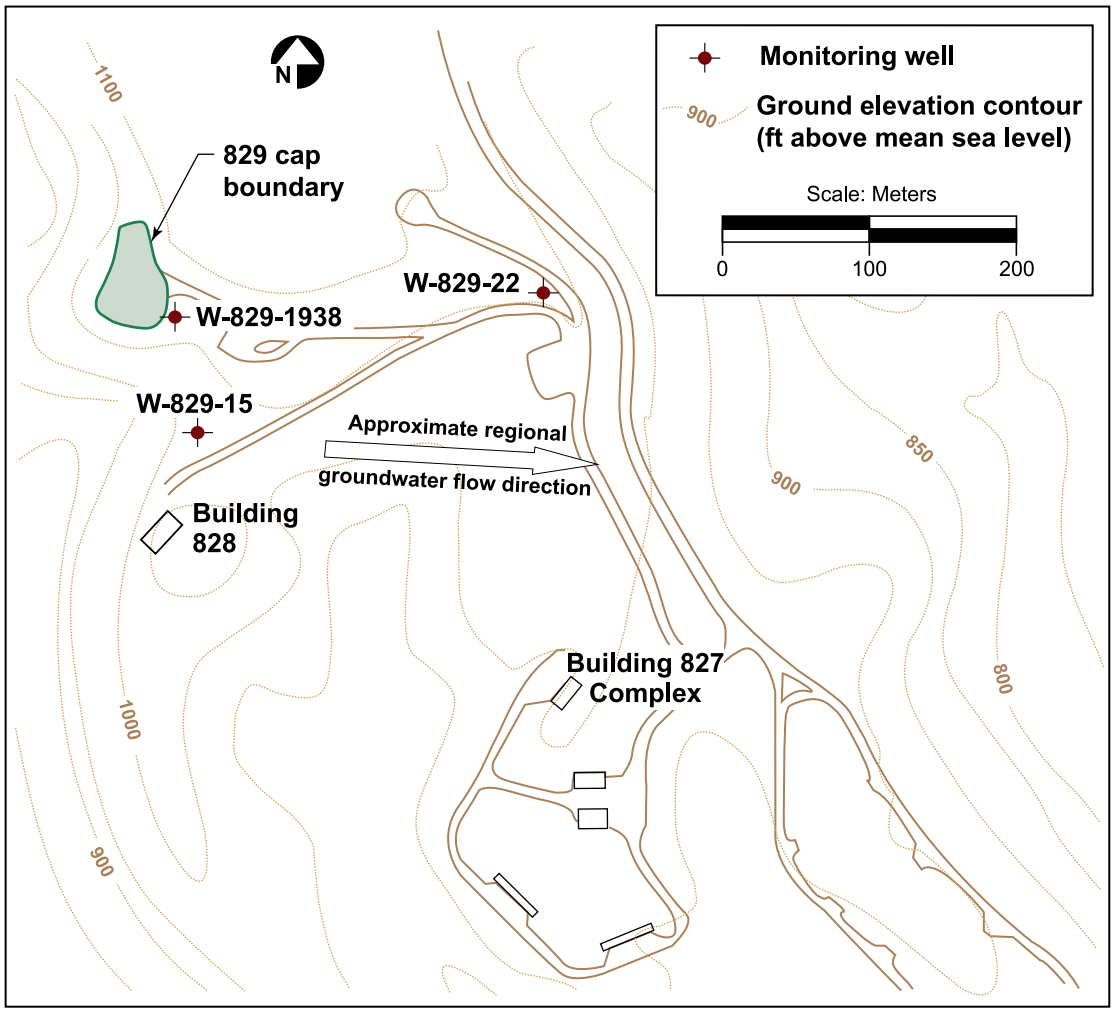


Figure 5-17. Locations of Building 829 closed burn pit compliance groundwater monitoring wells

No new release of COCs to groundwater from the closed Burn Facility is indicated by the monitoring data obtained during 2005. For a detailed account of compliance monitoring of the closed burn pit during 2005, including tables and graphs of groundwater COC analytical data, see *LLNL Experimental Test Site 300—Compliance Monitoring Program for the Closed Building 829 Facility—Annual Report 2005* (Revelli 2006b).

During 2005, no explosive COCs were detected above their respective reporting limits (RLs) in groundwater samples from any of the three monitoring wells. Among the organic COCs, only DEHP was reported to be above its RL in samples from one of the three wells (W-829-22); however, these DEHP results were eventually traced to laboratory contamination. The inorganic constituents that were detected in samples from the two established wells (W-829-15 and W-829-22) show concentrations that do not

differ significantly from background concentrations for the deep aquifer beneath the Explosives Process Area (Webster-Scholten 1994).

With one exception, the concentrations of inorganic COCs detected in the new well (W-829-1938) were consistent with background concentrations reported for the other wells that were also sampled for this network. Only nickel (detected at 14 µg/L, 5.1 µg/L, and 8.6 µg/L in the second and third quarter 2004 samples and in the first quarter 2005 sample, respectively) had not previously been detected in groundwater samples from this monitoring network. Nickel, however, is typically found in Site 300 groundwater at background concentrations of 21 µg/L (Webster-Scholten 1994). Based on the eight quarters of data currently available, LLNL has proposed statistical limits for nickel, and the other COCs detected above their respective RLs, at well W-829-1938 (Revelli 2006b). Continued quarterly sampling at well W-829-1938 will provide additional data to better establish background concentrations and statistically determined limits of concentrations in accordance with state regulations.

Water Supply Well

Water supply well 20, located in the southeastern part of Site 300 (**Figure 5-13**), is a deep, high-production well. The well is screened in the Neroly lower sandstone aquifer ($Tnbs_1$) and can produce up to 1500 L/min of potable water. As planned for surveillance purposes, LLNL obtained groundwater samples quarterly during 2005 from well 20. Groundwater samples were analyzed for inorganic COCs (mostly metals), VOCs, general radioactivity (gross alpha and gross beta), and tritium activity.

Quarterly measurements of groundwater from well 20 do not differ significantly from previous years. As in past years, the primary potable water supply well at Site 300 showed no evidence of contamination. Gross alpha, gross beta, and tritium activities were very low and are indistinguishable from background level activities.

Off-site Surveillance Wells and Springs

As planned for surveillance purposes, LLNL obtained groundwater samples from two off-site springs and ten off-site wells during 2005. With the exception of one well, all off-site monitoring locations are near Site 300. The exception, well VIE2, is located at a private residence 6 km west of the site. It represents a typical potable water supply well in the Altamont Hills. One stock watering well, MUL1, and two stock watering springs, MUL2 and VIE1, are adjacent to Site 300 on the north. Eight wells, CARNRW1, CARNRW2, CDF1, CON1, CON2, GALLO1, STONEHAM1, and W35A-04, are adjacent to the site on the south (**Figure 5-13**). Well W-35A-04 is a DOE CERCLA well that was installed off site for monitoring purposes only. The remaining seven wells south of Site 300 are privately owned and were

constructed to supply water either for human consumption, stock watering, or fire suppression. They are monitored to determine the concentrations of dissolved constituents in the groundwater beneath the Corral Hollow Creek flood plain.

Groundwater samples were obtained quarterly during 2005 at six of the off-site surveillance well locations south of Site 300. As planned, CARNRW1 and CON2 samples were analyzed for VOCs; samples from well CARNRW1 were also sampled for perchlorate and tritium. Samples from CARNRW2, CDF1, CON1, and GALLO1 were analyzed quarterly for inorganic COCs (mostly metals), general radioactivity (gross alpha and beta), tritium activity, explosive compounds (HMX and RDX), and VOCs (EPA method 502.2). Additional annual analyses were conducted on third-quarter samples for uranium activity and extractable organic compounds (EPA method 625).

Groundwater samples were obtained once (annually) during 2005 from the remaining off-site surveillance monitoring locations—MUL1, MUL2, and VIE1 (north of Site 300); VIE2 (west of Site 300); and STONEHAM1 and W-35A-04 (south of Site 300). Samples were analyzed for inorganic COCs (mostly metals), general radioactivity (gross alpha and beta), tritium and uranium activity, explosive compounds (HMX and RDX), VOCs, and extractable organic compounds (EPA method 625).

Generally, no COC attributable to LLNL operations at Site 300 was detected in the off-site groundwater samples. Arsenic and barium were widely detected at the off-site locations, but their concentrations were below MCLs and their occurrence is consistent with natural sources in the rocks. Scattered detections of metals are probably related to metals used in pumps and supply piping. As in past years, TCE was detected at concentrations of less than 1 µg/L in the groundwater samples obtained from well GALLO1. Previous CERCLA remedial investigations concluded that the TCE in the GALLO1 well water was likely caused by a localized surface spill on the property, possibly solvents used to service the private well (Webster-Scholten 1994). Radioactivity measurements of off-site groundwater are generally indistinguishable from background activities.

Environmental Impact on Groundwater

Groundwater monitoring at the Livermore site and Site 300 and their environs indicates that LLNL operations have minimal impact on groundwater beyond the site boundaries. During 2005, neither radioactivity nor concentrations of elements or compounds detected in groundwater were confirmed to be above potable water MCLs.

Other Monitoring Programs

Rainwater

Rainwater is sampled and analyzed for tritium activity in support of DOE Order 5400.5, Radiation Protection of the Public and the Environment. LLNL collects rainwater samples according to written standardized procedures which are summarized in the *Environmental Monitoring Plan* (Woods 2005). Rainwater is collected in stainless-steel buckets at fixed locations. The buckets are in open areas and are mounted about 1 m above the ground to prevent collection of splashback water. Rainwater samples are decanted into 250 mL amber glass bottles with Teflon-lined lids. The tritium activity of each sample is measured at a contracted laboratory by a scintillation counting method equivalent to EPA Method 906 that has a low reporting limit of about 3.7 Bq/L (100 pCi/L). All analytical results are included in the file "Ch5 Other Waters" provided on the report CD.

Livermore Site and Environs

Historically, the tritium activity measured in rainwater in the Livermore Valley was caused by atmospheric emissions of HTO from stacks at LLNL's Tritium Facility (Building 331), and prior to 1995, from the former Tritium Research Laboratory at Sandia/California. During 2005, tritium activity in air-moisture and, thence, in rainwater at the Livermore site and in the Livermore Valley, resulted primarily from atmospheric emissions of HTO from stacks at Building 331. Atmospheric emissions of HTO from Building 331 are shown in **Figure 4-4**. Other sources include the Waste Management Area (WMA) at Building 612 and the DWTF (see Chapter 4).

Rain sampling locations are shown in **Figure 5-18**. The fixed locations are used to determine the areal extent of detectable tritium activity in rainwater. During 2005, LLNL collected sets of rainwater samples following two rain events in the Livermore Valley and two rain events at Site 300. All of the rainwater sampling dates correspond to storm water runoff sampling.

Although the Livermore site rainwater has exhibited elevated tritium activities in the past (Gallegos et al. 1994), during 2005, no on-site measurement of tritium activity was above the MCL of 740 Bq/L (20,000 pCi/L) established by the EPA for drinking water. As in past years, the on-site rainwater sampling location B343 showed the highest tritium activity for the year, 12 Bq/L (324 pCi/L), for the rain event that was sampled on January 11. The maximum tritium activity measured in an off-site rainwater sample during 2005 was an estimated value below the minimum

reporting limit of 3.7 Bq/L (100pCi/L) in the rainwater sample obtained on January 11 from location VET (**Figure 5-18**).

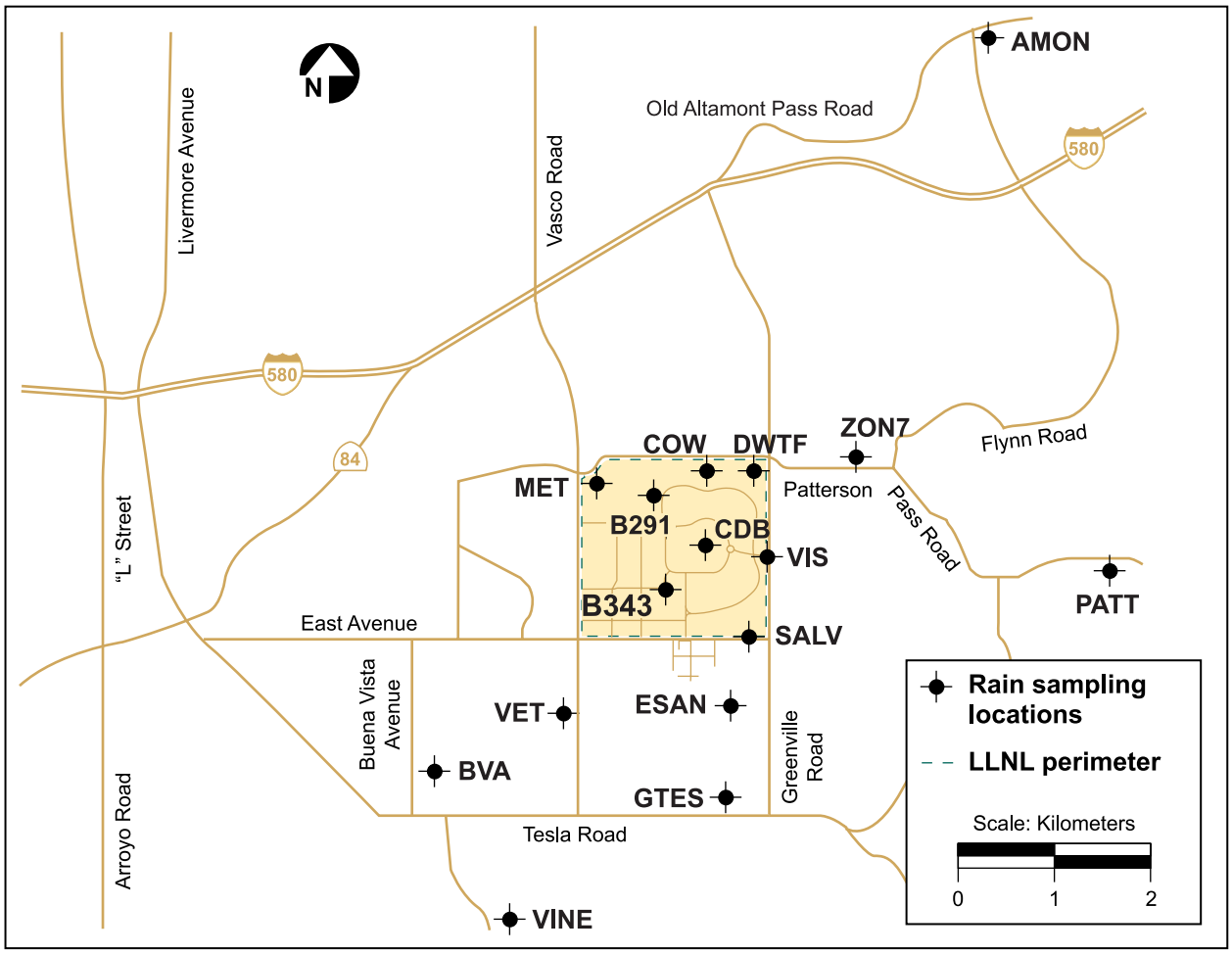


Figure 5-18. Rain sampling locations, Livermore site and Livermore Valley, 2005

Site 300 and Environs

Three on-site locations (COHO, COMP, and TNK5) were positioned to collect rainfall for tritium activity measurements at Site 300 during 2005 (**Figure 5-10**). During 2005, two rain events were sampled. As in past years, none of the rainwater samples from monitoring locations at Site 300 during 2005 had tritium activities above the analytical laboratory reporting limit of 3.7 Bq/L.

Livermore Valley Surface Waters

LLNL conducts additional surface water surveillance monitoring in support of DOE Order 5400.5, Radiation Protection of the Public and the Environment. Surface and drinking water near the Livermore site and in the Livermore Valley are sampled at the locations shown in **Figure 5-19**. Off-site sampling locations DEL, ZON7, DUCK, ALAG, SHAD, and CAL are surface water bodies; of these, DEL, ZON7, and CAL are also drinking water sources, GAS, ORCH, and TAP are drinking water outlets. Radioactivity data from drinking water sources are used to calculate drinking water statistics (see **Table 5-13**).

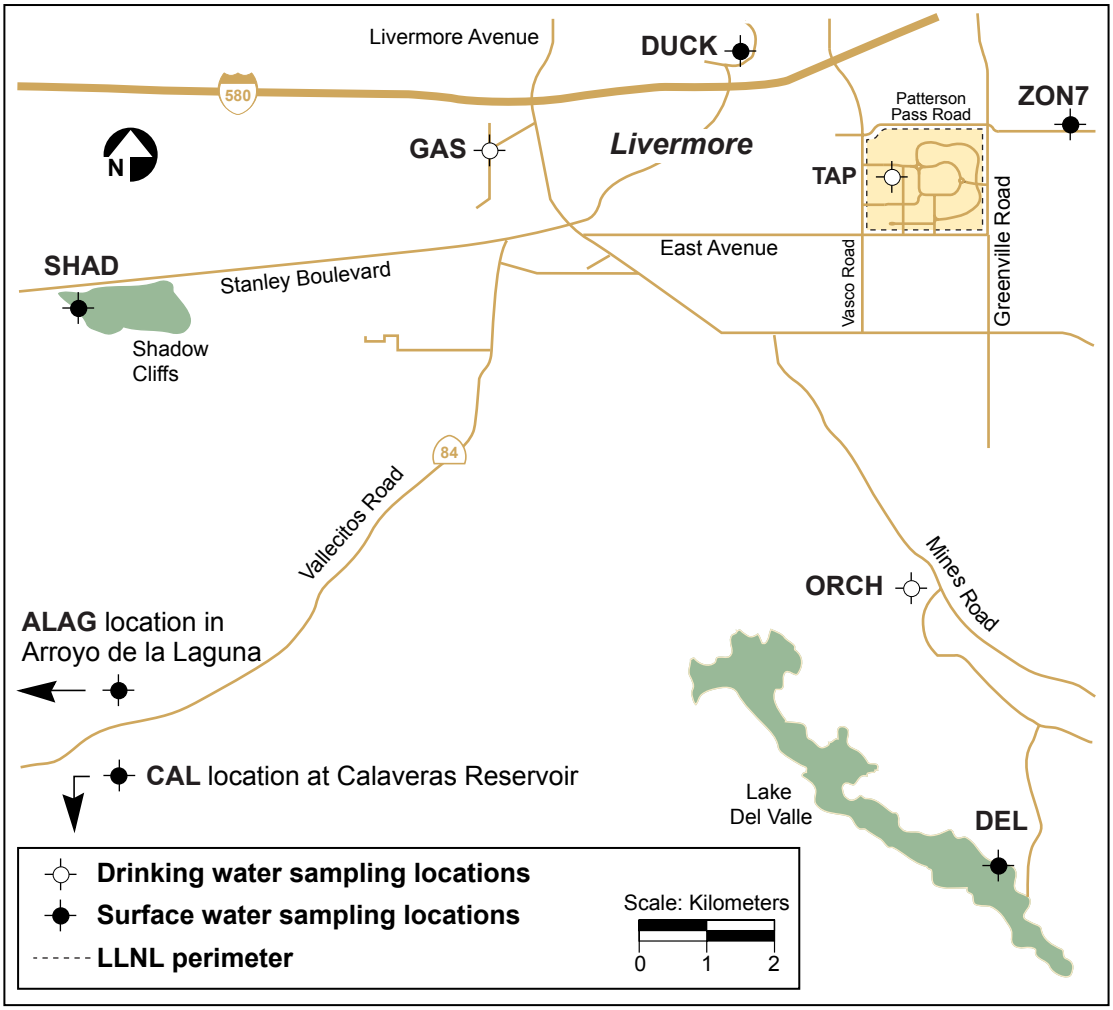


Figure 5-19. Livermore Valley surface and drinking water sampling locations, 2005

Samples are analyzed according to written standardized procedures summarized in the *Environmental Monitoring Plan* (Woods 2005). LLNL sampled these locations semiannually, in January and July 2005, for gross alpha, gross beta, and tritium. All analytical results are included in the file "Ch5 Other Waters" provided on the report CD.

The median activity for tritium in surface and drinking waters was estimated from calculated values to be below the analytical laboratory's minimum detectable activities, or minimum quantifiable activities. In fact, no tritium above the analytical laboratory's minimum detectable activities was detected in any sample. Median activities for gross alpha and gross beta radiation in surface and drinking water samples were both less than 5% of their respective MCLs. Maximum activities detected for gross alpha and gross beta, respectively, were 0.054 Bq/L (1.5 pCi/L) and 0.381 Bq/L (10.3 pCi/L); both were less than 25% of their respective MCLs (see **Table 5-13**). Historically, concentrations of gross alpha and gross beta radiation have fluctuated around the laboratory minimum detectable activities. At these very low levels, the counting error associated with the measurements is nearly equal to, or in many cases greater than, the calculated values so that no trends are apparent in the data.

Since 1988, when measurements began, water in the LLNL swimming pool had the highest tritium activities because it was close to tritium sources within LLNL. After the first quarter of 2004 and the draining of the swimming pool in July 2004, the Drainage Retention Basin became the closest routinely monitored surface water to the Tritium Facility (Building 331).

Table 5-13. Radioactivity in surface and drinking waters in the Livermore Valley, 2005

Locations	Tritium (Bq/L)	Gross alpha (Bq/L)	Gross beta (Bq/L)
All locations			
Median	–2.06	0.010	0.080
Minimum	–5.07	–0.028	0.011
Maximum	0.45	0.054	0.381
Interquartile range	1.09	0.019	0.069
Drinking water locations			
Median	–2.29	0.010	0.057
Minimum	–5.07	–0.028	0.011
Maximum	–1.26	0.025	0.381
Interquartile range	0.46	0.013	0.140
Drinking water MCL	740	0.555	1.85

Note: A negative number means the sample radioactivity was less than the background radioactivity.

Drainage Retention Basin Release

The DRB was constructed and lined in 1992 after remedial action studies indicated that infiltration of storm water from the existing basin increased dispersal of groundwater contaminants. Located in the center of the Livermore site, the DRB can hold approximately 45.6 ML (37 acre-feet) of water. Previous *Environmental Reports* detail the history of the construction and management of the DRB (see Harrach et al. 1995, 1996, 1997). Beginning in 1997, LLNL discharges to the DRB included routine treated groundwater from TFD and TFE, and from related portable treatment units. These discharges contribute a year-round source of water entering and exiting the DRB. The discharge rate is approximately 380 L/min (100 gal/min). Storm water runoff still dominates wet weather flows through the DRB, but discharges from the treatment facilities now constitute a substantial portion of the total water passing through the DRB.

The SFBRWQCB regulates discharges from the DRB. The document *Drainage Retention Basin Monitoring Plan Change* (Jackson 2002) lists constituents of interest, sample frequencies, and discharge limits based on the Livermore site CERCLA Record of Decision (ROD) (U.S. DOE 1993), as modified by the *Explanation of Significant Differences for Metals Discharge Limits at the Lawrence Livermore National Laboratory Livermore Site* (Berg et al. 1997). The ROD established discharge limits for all remedial activities at the Livermore site to meet applicable, relevant, and appropriate requirements derived from laws and regulations identified in the ROD, including federal Clean Water Act, federal and state Safe Drinking Water Acts, and the California Porter-Cologne Water Quality Control Act. See Appendix B for the limits used.

The DRB sampling program implements requirements established by the SFBRWQCB. The program consists of monitoring wet and dry weather releases for compliance with discharge limits and performing routine reporting. For purposes of determining discharge monitoring requirements and frequency, the wet season is defined as October 1 through May 31, the period when rain-related discharges usually occur (Galles 1997). Discharge limits are applied to the wet and dry seasons as defined in the *Explanation of Significant Differences for Metals Discharge Limits at the Lawrence Livermore National Laboratory Livermore Site* (Berg et al. 1997) (wet season December 1 through March 31, dry season April 1 through November 30).

Discharge from the DRB is typically continuous because the evaporation rate is less than the flow into the DRB from storm water runoff and treated groundwater discharges. To characterize wet-season discharges, LLNL samples DRB discharges at location CDBX and the Livermore site outfall at location WPDC during the first release of the rainy season, and from a minimum of one additional release (chosen in conjunction with storm water

runoff sampling). During the dry season (June, July, August, September), samples are collected at the beginning of each discrete discharge event or monthly while discharge is continuous. Discharge sampling locations CDBX and WPDC are shown in **Figure 5-9**. LLNL collects samples at CDBX to determine compliance with discharge limits. Sampling at WPDC is performed to identify any change in water quality as the DRB discharges travel through the LLNL storm water drainage system and leave the site.

Written standardized sample collection procedures are summarized in the *Environmental Monitoring Plan* (Woods 2005). State-certified laboratories analyze the collected samples for chemical and physical parameters. All analytical results are included in the file "Ch5 Other Waters" provided on the report CD.

Water releases typically occurred continuously to maintain relatively low nutrient levels in the DRB and because treatment facility discharge to the DRB exceeded the evaporation rate. Samples collected at CDBX and WPDC exceeded only the pH discharge limits. The higher pH readings seen in the DRB discharge samples during the summer correspond to the peak of the summer algal bloom within the DRB. During 2005, total dissolved solids and specific conductance continued to reflect the levels found in groundwater discharged to the DRB. While some metals were detected, none were above discharge limits. All organics, pesticides, and PCBs were below analytical discharge limits. Gross alpha, gross beta, and tritium levels were well below discharge limits.

LLNL collects and analyzes samples for acute fish toxicity using fathead minnow (*Pimphales promelas*) and for chronic toxicity using three species (fathead minnow, water flea daphnid [*Ceriodaphnia dubia*], and green algae [*Selanastrum capricomutum*]). LLNL collects acute toxicity samples at the first wet-season release and from the four dry season sampling events from location CDBX. Samples for chronic fish toxicity were collected at location CDBX at the first wet-season release. Aquatic bioassays for toxicity showed no effects in DRB discharge water.

Site 300 Drinking Water System

LLNL samples large-volume discharges from the Site 300 drinking water distribution system that reach surface water drainage courses in accordance with the requirements of WDR 5-00-175, NPDES General Permit No. CAG995001. The monitoring and reporting program that LLNL developed for these discharges was approved by the CVRWQCB.

Discharges that are subject to sampling under WDR 5-00-175 and their monitoring requirements are:

- Drinking water storage tanks: Discharges that have the potential to reach surface waters are monitored.
- System flushes: One flush per pressure zone per year is monitored for flushes that have the potential to reach surface waters.
- Dead-end flushes: All flushes that have the potential to reach surface waters and any discharge that continues for more than four months are monitored.

Discharges must comply with the effluent limits for residual chlorine and pH established by the permit; that is, residual chlorine must not be greater than 0.02 mg/L, and the pH must be between 6.5 and 8.5. Discharges are also visually monitored to ensure that no erosion results and no other pollutants are washed into surface waters. To meet the chlorine limit, drinking water system discharges with the potential to reach surface waters are dechlorinated.

Sample collection procedures are discussed in the *Lawrence Livermore National Laboratory Site 300 Water Suppliers' Pollution Prevention and Monitoring and Reporting Program* (Mathews 2000). Grab samples are collected in accordance with written standardized procedures summarized in the *Environmental Monitoring Plan* (Woods 2005). Residual chlorine and pH are immediately analyzed in the field using a spectrophotometer and calibrated pH meter, respectively.

Samples are collected at the point of discharge and at the point where the discharge flows into a surface water. If the discharge reaches Corral Hollow Creek, samples are collected at the upstream sampling location, CARW2, and the downstream sampling location, GEOCRK.

During March 2005, the replacement of a fire hydrant flow valve necessitated the discharge of approximately 6000 gallons of water. This water was dechlorinated and released through a diffuser; sampling measurements, completed at the discharge location, showed the pH and residual chlorine to be in compliance with WDR 5-00-175 discharge requirements. Additionally, small volumes of water (less than 2000 gallons) were discharged in the first quarter of 2005, as a result of routine pressure tests conducted by the Site 300 fire department. Because of the nature of fire department activities, these small-volume discharges were not monitored. The annual pressure zone testing, required by the CVRWQCB, was completed during the third quarter, when LLNL conducted flushing of the drinking water system for water quality purposes. These system flush releases were monitored and met the effluent limits. All 2005 releases from the Site 300 drinking water system quickly percolated into the drainage ditches or streambed, and did not reach Corral Hollow Creek, the potential receiving water (Raber 2004). Monitoring results are detailed in the quarterly self-monitoring reports to the CVRWQCB.

Site 300 Cooling Towers

On August 4, 2000, the CVRWQCB rescinded WDR 94-131, NPDES Permit No. CA0081396, which previously governed discharges from the two primary cooling towers at Site 300. The CVRWQCB determined that these cooling towers discharge to the ground rather than to surface water drainage courses. Therefore, the CVRWQCB is issuing a new permit to incorporate these cooling tower discharges, and other low-threat discharges, going to ground. Pending the issuance of the new permit, LLNL continues to monitor the cooling tower wastewater discharges following the WDR 94-131 monitoring requirements at the direction of CVRWQCB staff.

Two primary cooling towers, located at Buildings 801 and 836A, regularly discharged to the ground during the first quarter of 2005. As in past years, blowdown flow from the cooling towers located at these two buildings was monitored biweekly and total dissolved solids (TDS) and pH were monitored quarterly. On April 13, 2005, the cooling tower at Building 836A was replaced with an air cooled system; discharges and monitoring were discontinued at that time. Biweekly flow and quarterly TDS and pH monitoring at cooling tower 801 continued throughout the year. The 13 secondary cooling towers routinely discharge to percolation pits under a waiver of Waste Discharge Requirements from the CVRWQCB. Cooling tower locations are shown in **Figure 5-20**.

Written standardized sample collection procedures are summarized in the *Environmental Monitoring Plan* (Woods 2005). To determine the effects of the cooling tower blowdown on Corral Hollow Creek, LLNL quarterly monitors pH, both upstream (background) and downstream of the cooling tower discharges, whenever the creek is flowing. CARW2 is the upstream sampling location, and GEOCRK is the downstream sampling location (**Figure 5-20**).

The GEOCRK sampling location is fed by sources from Site 300 and neighboring lands. Therefore, even when the upstream location is dry, there may be flow at GEOCRK. Field pH measurements, taken by LLNL using calibrated meters, are used to monitor Corral Hollow Creek. LLNL also performs the required visual observations that are recorded on field tracking forms along with the field pH measurements.

If the blowdown flow from any of the 13 secondary cooling towers is diverted to a surface water drainage course, the discharge is sampled for pH and TDS immediately. If the discharge continues, that location is monitored for the same constituents and on the same schedule as the primary cooling towers.

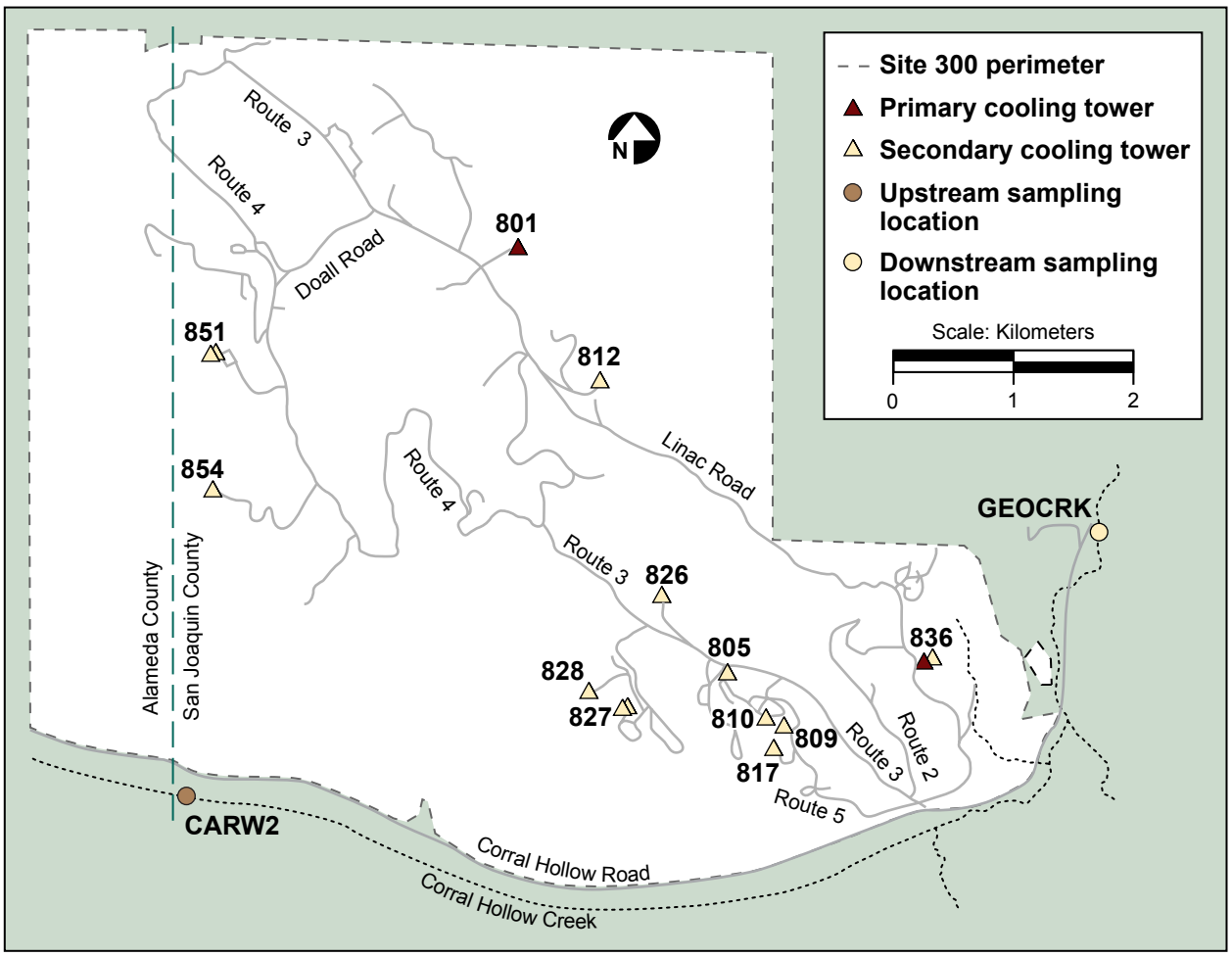


Figure 5-20. Cooling tower locations and receiving water monitoring locations, Site 300, 2005

Monitoring results in 2005 indicate that all discharges from the Building 801 and Building 836A cooling towers were below the maximum TDS (2400 mg/L) and pH (10) values that were previously imposed for discharges to surface water drainage courses under WDR 94-131. The blowdown flow rates from these towers were typical of volumes reported in recent years, except for two slightly elevated values (approximately twice the median value) that were recorded at the Building 801 tower. On July 14 and November 1, the blowdown flow rates were reported as 16,012 L/day and 16,588 L/day, respectively. In both cases, the flow readings for the preceding and following observation periods reported typical volumes, indicating that these high flows were transient events. No flow was observed at either the CARW2 or GEOCRK locations during the periods in question. **Table 5-14** summarizes the data from the quarterly TDS and pH monitoring, as well as the biweekly measurements of blowdown flow rate.

Table 5-14. Summary data from monitoring of primary cooling towers, Site 300, 2005

Test	Tower no.	Minimum	Maximum	Median	Interquartile range	Number of samples
Total dissolved solids (TDS) (mg/L)	801	1,000	2,200	1,300	—[a]	4
	836A	980	980	—[b]	—[a]	1[b]
Blowdown (L/day)	801	0	16,588	8,146	1,173	25[c]
	836A	1,393	2,514	2,241	589	7[b]
pH (pH units)	801	8.7	9.1	8.9	—[a]	4
	836A	8.8	8.8	—[b]	—[a]	1[b]

a Too few data points to determine

b Only one quarterly sample and seven biweekly blowdown measurements were collected. The monitoring program at cooling tower 836A was discontinued April 13, 2005, after that cooling tower was replaced with an air-cooled system.

c One biweekly blowdown measurement could not be collected because the area around Tower 801 was closed.

The biweekly observations at CARW2 and GEOCRK reported flowing conditions for both sampling locations during the first four months (January through April) of 2005. The resulting field pH measurements were between 7.56 and 8.96 at the CARW2 location, and between 7.97 and 8.99 at GEOCRK. These results indicate essentially no change in pH between the upstream and downstream locations. Dry or no flow conditions were reported for the remaining eight months of 2005. Visual observations of Corral Hollow Creek were performed each quarter, and no visible oil, grease, scum, foam, or floating suspended materials were noted in the creek during 2005.

No drinking water or cooling tower water releases from Site 300 reached Corral Hollow Creek. There is no evidence of any adverse environmental impact on surrounding waters resulting from these LLNL activities during 2005.